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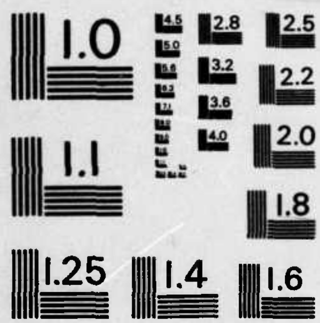

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AVIATION FUEL FORECASTING AT BASE LEVEL USING PROGRAMMED AIR FORCE FLYING ACTIVITIES

THESIS

J.D. Richardson, Jr.
1st Lt, USAF

Claude F. Stocky
Capt, USAF

AFIT/GLM/LSM/84S-61

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

84 12 03 144

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AFIT/GLM/LSM/84S-61

AVIATION FUEL FORECASTING AT BASE LEVEL USING PROGRAMMED AIR FORCE FLYING ACTIVITIES

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

James D. Richardson, Jr, B.A.

First Lieutenant, USAF

Claude F. Stocky, B.S.

Captain, USAF

September 1984

Approved for public release; distribution unlimited

Acknowledgements

We wish to express our sincere thanks and appreciation to our wives, Nancy and Eileen, and our families for understanding our need to be away from home so often during this research effort. A special thanks goes to our advisor, Dr Jeff Daneman, for his patience and expert guidance. Finally, special appreciation is given to Lt Col Lloyd Roecker and his entire staff at the Energy Directorate, Headquarters, Air Training Command for their assistance in providing the data needed for conducting this research.

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Abstract

The current Air Force base-level petroleum requirements determination and validation process involves manual computations and analysis at both base and Major Command levels in determining forecast quantities for procurement by the Defense Fuel Supply Center (DFSC). These forecasts often rely heavily on past consumption as the primary basis for future requirements and are often not as accurate as DFSC would like. This thesis sought ~~The purpose of this research is~~ to investigate an alternate forecast method based on programmed flying hours that may more accurately represent and predict future requirements.

Past JP-4 fuel consumption data combined with past programmed and actual flying hours was collected from seven Air Training Command bases. This data was ~~subsequently~~ analyzed using statistical regression analysis which produced consumption coefficients associated with each type of aircraft assigned to each base studied. These prediction coefficients were assembled with mean transient and non-fly consumption and tested using past programmed flying hours multiplied times the prediction coefficients. → over

cont

The overall results indicated that the regression models' forecast, compared against past forecasts by base and their actual consumption yielded more accurate forecasts in 17 ~~seventeen~~ out of 21 ~~twenty-one~~ time periods.

Several recommendations were also made by the authors that may enhance future studies of this nature.

AVIATION FUEL FORECASTING AT BASE LEVEL
USING AIR FORCE PROGRAMMED FLYING ACTIVITIES

I. Introduction

Background

Petroleum has rapidly become one of the most critical and expensive resources used by the Department of Defense (DoD) in meeting its national defense objectives. A relatively inexpensive commodity prior to the early 1970s, costs associated with the distribution and maintenance of fuel levels were given little consideration until recent years. The primary concern was to have more than enough fuel to meet peacetime and wartime operating needs. Over the past ten years, however, oil prices have increased over 300 percent in inflation adjusted dollars (6:4-1).

The Defense Logistics Agency's Defense Fuel Supply Center (DFSC) is responsible for providing effective and economical support of all bulk petroleum requirements, serving all U.S. military service components and other Federal agencies. Based on forecasted requirements provided by each service, DFSC develops and awards contracts for the petroleum products requested.

Petroleum forecasts provided by the services have not always been accurate. Overstated forecasts have adversely affected relations between DFSC and the petroleum suppliers by leaving the suppliers with excess quantities of fuel that

were originally negotiated but never purchased (16:2). Understated forecasts have also had a negative impact on DFSC's effectiveness. It can take up to 90 days to negotiate or to amend a contract with an oil supplier and occasionally amending an existing contract is not possible because of other contractual commitments by the oil company (4:18). The time lag associated with making up the difference for an understated forecast could affect a base's overall readiness posture by forcing it to seek permission to violate some of its War Reserve Material Stock (WRM), or causing DFSC to revise peace time and Emergency Distribution Plans to cover the shortage.

Given these inaccuracies and the increase in fuel costs, currently eight billion dollars a year (3), DFSC is concerned with improving inventory management techniques which will reduce the costs associated with the procurement and distribution of petroleum products (16:5). Prior to 1982 DFSC's bulk petroleum contracts specified a minimum order of $100. Many contracts have since been changed to require total orders to be at least 75 percent of the fuel specified in the contract (14:1-2). By doing so DFSC hopes to achieve lower prices by reducing the risk associated with government fuel contracts. However, this increases the need for more accurate fuel forecasting.

DFSC's implementation of the Centrally Managed Allotment (CMA) funding concept in October 1982 further

increased the need for more accurate fuel forecasting by the services and provided stricter controls of activities ordering fuel from DFSC direct delivery contracts. (Direct delivery is delivery of fuel from a commercial contractor direct to the user as opposed to a DFSC supply terminal which would issue fuel to the using activity). Under this funds control program, military activities were expected to receive within ten percent or one million gallons of the total projected requirement (whichever amount was less). Any excessive variations were to be reported, and estimates revised and resubmitted as soon as possible. Unless otherwise indicated by the using activity, fuel requirements were assumed to be constant from month to month, equaling one twelfth of the annual forecasted requirement. Furthermore, the Source Identification and Ordering Authorization Document (SIOATH) which authorizes the quantity and resupply source for each activity would also become a funds control document (14:1-2). This would restrict ordering authority to the exact quantities authorized by DFSC. This is in contrast to present procedures which allow the last order received by barge, tanker or pipeline to be double the undelivered balance or the undelivered balance plus 30,000 barrels, whichever is less (13:II-4-12). The program, however, was terminated because the services could not achieve the forecasting accuracy needed (24). Instead, present efforts require

ordering activities to review projected requirements against balances and notify DFSC offices whenever orders are expected to fall short of the total contract requirement by fifteen percent or more (13:II-4-13).

Problem Statement

Using present procedures, some Air Force bases are unable to predict future petroleum consumption as accurately as desired by DFSC. Examination of variations between initial forecasts and actual consumption for a selected group of Air Force bases show variations as great as 27 percent (see figures 1.1,1.2,1.3).

Purpose

The purpose of this study is to describe the current requirements determination process and to investigate an alternative forecast method which may more accurately determine petroleum requirements.

Scope

Given the complexity of the types and uses of fuel used within the DoD, it would be difficult to research a forecasting method that would apply to all uses and types of fuel. Therefore, the scope of this study will be directed toward finding a more accurate base-level forecasting technique for computing aviation jet fuel (avfuel or JP-4) requirements for the Air Force, which constitute about 55

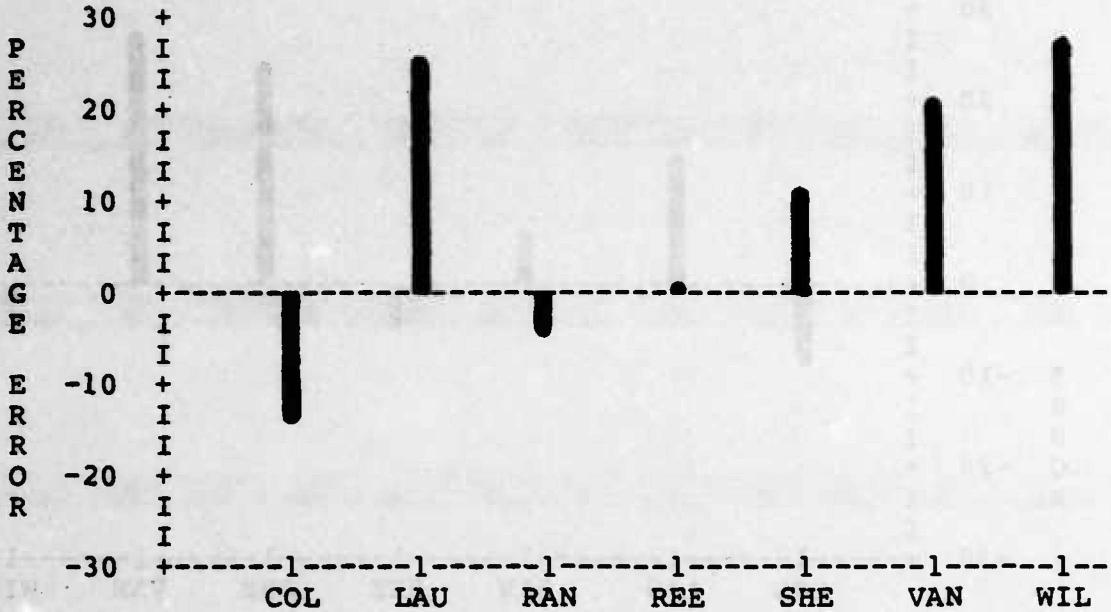

Figure 1.1 Air Training Command FY 82 Initial Forecast Accuracy, JP-4 [Ref: Table 4.1]

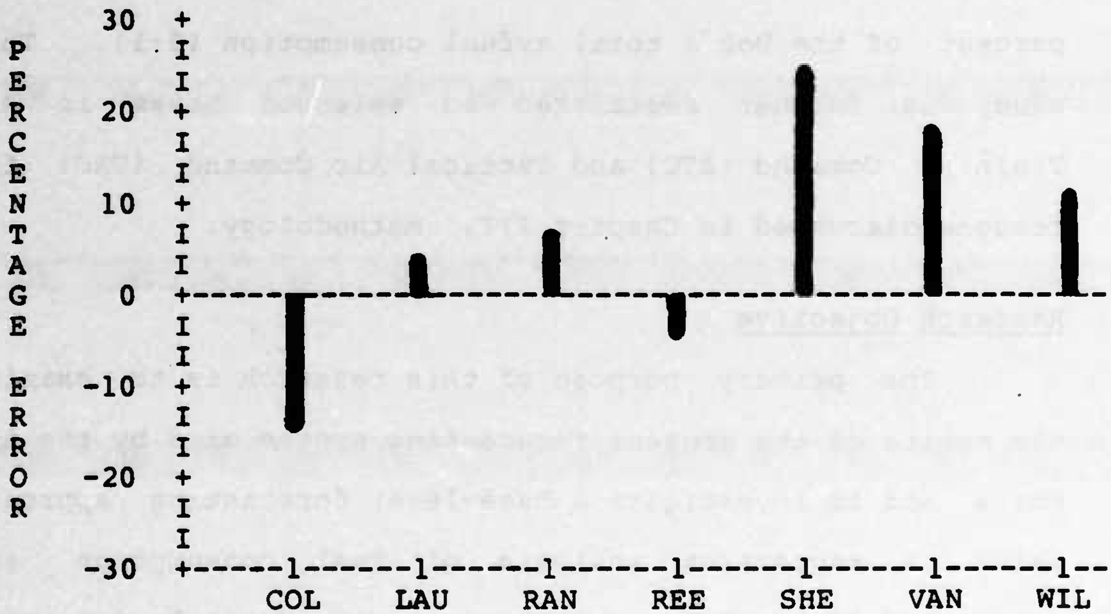

Figure 1.2 Air Training Command FY 83 Initial Forecast Accuracy, JP-4 [Ref: Table 4.1]

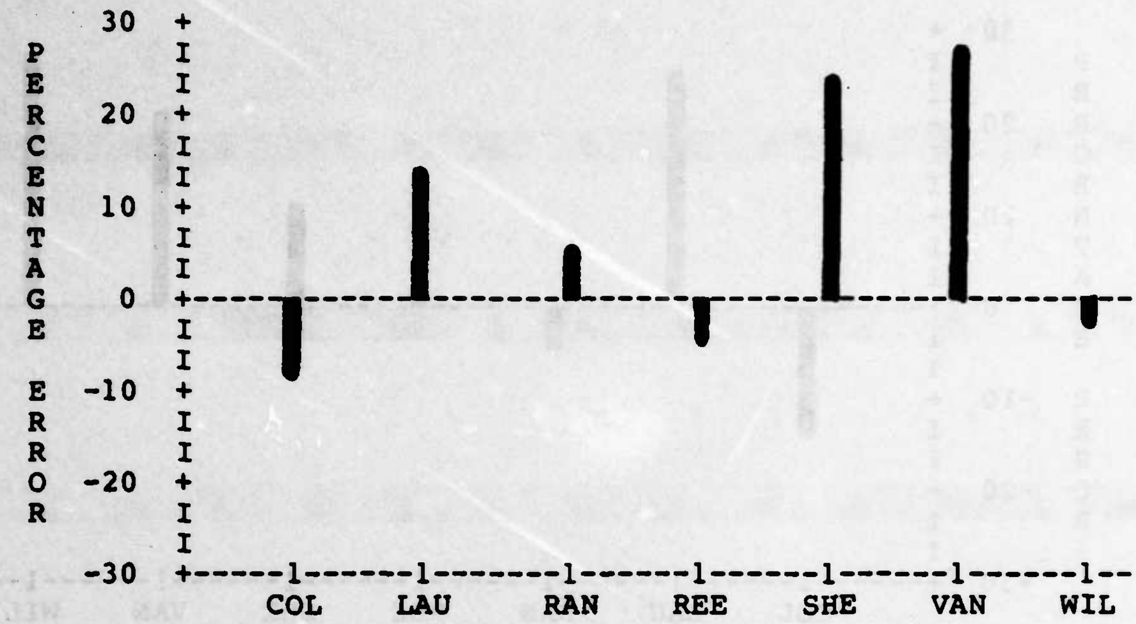

Figure 1.3 Air Training Command FY 84 Initial Forecast Accuracy, JP-4 [Ref: Table 4.1]

percent of the DoD´s total avfuel consumption (8:1). This study is further restricted to selected bases in Air Training Command (ATC) and Tactical Air Command (TAC) for reasons discussed in Chapter III, Methodology.

Research Objective

The primary purpose of this research is to examine the merits of the present forecasting system used by the Air Force and to investigate a base-level forecasting approach using a regression analysis of fuel consumption and programmed flying hours, which may more accurately determine future petroleum requirements.

Research Questions

In the process of conducting this research, the following questions will be answered:

1. What degree of accuracy does the present forecast system yield for the command studied?

2. What degree of accuracy does programmed hours have in predicting actual flying hours?

3. What degree of accuracy does programmed flying hours yield in predicting home station aircraft fuel requirements?

4. What degree of accuracy does the average transient aircraft issue rate yield in predicting future transient aircraft requirements?

5. What degree of accuracy does the average non-fly issue rate yield in predicting future non-fly requirements?

6. Is there strong correlation between non-fly issues and programmed flying hours, and if so, what degree of accuracy does programmed flying hours yield in predicting non-fly fuel requirements?

7. Combining the various predictors for computing home station aircraft, transient aircraft and non-fly fuel requirements what is the overall accuracy of this type model in predicting a base's fuel requirements? Does it yield better results than the present method?

II. Literature Review

Introduction

The purpose of this literature review is to provide information and background that is pertinent to the overall research objectives of this study. Using various manuals, regulations, and policies dealing with Air Force petroleum requirements determination and literary articles addressing various forecasting techniques, this review will attempt to familiarize the reader with adequate background information and help to justify this research. Additionally, since written literature does not sufficiently cover requirements determination, the use of telephone interviews of key personnel associated with the requirements determination and contracting processes will be included. This review covers the following major areas:

1. A background of DFSC and Det 29 with their internal and external interactions;

2. The current requirements determination process used by Det 29 and the Major Commands;

3. The procurement and distribution process;

4. Forecasting criteria and a brief review of forecasting models with emphasis on regression analysis;

5. A review of Janke and Pohlen's research on computer-aided forecasting models for requirements determination of petroleum products for the Department of Defense (16), and;

6. Information pertaining to Air Force Regulation 173-13, U.S. Air Force Cost and Planning Factors (12).

DFSC and Det 29 Background and Functional Relationships

The Defense Fuel Supply Center is responsible for purchasing fuel and petroleum products and distributing them to U.S. Armed Forces around the world and to specified Federal agencies (7:11).

Located at Cameron Station in Alexandria, Virginia, DFSC is the Defense Logistics Agency's (DLA) center for integrated material management of all bulk petroleum and coal used by the Department of Defense. DFSC is responsible for insuring that adequate inventories are available for efficient distribution to its customers. It is also responsible for purchasing petroleum for the Strategic Petroleum Reserve (SPR) and spends nearly eight billion dollars annually on petroleum procurement for the SPR and its DoD and Federal customers.(3; 7:11)

The Defense Fuel Supply Center was established in 1945 for the purpose of coordinating all petroleum purchases for the Department of War (later DoD). Between 1945 and 1962 DFSC experienced several name changes. In 1962, DFSC became a charter member of the Defense Supply Agency (presently known as the Defense Logistics Agency) and was named the Defense Petroleum Supply Center. In 1964 it was renamed the Defense Fuel Supply Center, the name by which it

is known today. In 1973, DFSC became DoD´s Integrated Material Manager for bulk petroleum worldwide.(16:11)

The Defense Fuel Supply Center is comprised of three internal directorates: the Directorate of Supply Operations; the Directorate of Procurement and Production; and the Directorate of Technical Operations (13: I-1-19). In addition, DFSC operates five Defense Fuel Regions (DFR) in the continental United States (CONUS) and six Defense Fuel Support Points (DFSP) in overseas locations. These DFRs and DFSPs serve as DFSC´s customer service field representatives on fuel-related matters. They also can serve as bulk storage terminals for DLA owned fuel. (7:11)

Detachment 29 (Det 29) is an extension of the Directorate of Energy Management, San Antonio Air Logistics Center (SA-ALC), and is colocated with DFSC at Cameron Station, Virginia (8:13). Det 29 is the Service Control Point (SCP) for all Air Force fuel requirements. It serves as the direct communications link between DFSC and Air Force petroleum requirements.

Requirements Determination Process

Presently, DFSC relies on each service component, through their SCP, to provide projected annual (fiscal) fuel requirements. Each SCP assembles bulk aviation and ground fuel requirements for its service and submits these requirements to DFSC as Military Interdepartmental Purchase

Requests (MIPR) (8:13). The MIPRs normally represent the fuel requirements for a subsequent fiscal year for each activity location (post, base, or station), plus any additional requirements for special exercise, initial tank fills, and building up of service-owned inventories (13:II-1-3).

DFSC, in turn, uses the MIPR as a basis for solicitation of contracts between commercial refineries and the DFRs and DFSPs. Once the contracts are awarded, the DFRs and DFSPs notify each military activity within their geographical region of the quantity and petroleum contract source(s) they will use for resupply. These quantities and sources are identified on a Source Identification Ordering Authorization and sent to each activity (13:II-4-1;11:19). The SCP for the Air Force, Det 29, is the primary office of responsibility for establishing Air Force petroleum requirements. Det 29 relies on information contained in the Chief of Staff of the Air Force´s Five Year Plan and the D022 report from SA-ALC in determining fuel requirements (9:13).

The Five Year Plan essentially contains information about projected aircraft flying hours for each Mission, Design, and Series (MDS) aircraft in the Air Force´s inventory (1). The D022 report is an integrated conglomerate of management information reports. Data and information from the Monthly Fuels Management Data Report (M-34), Monthly

Sales Analysis Report (M-27), general ledger information from the Air Force Accounting and Finance Center in Denver Colorado, and inventory status from the Defense Energy Information Report I (DEIS-I) are contained in the D022 report (22).

Information from the Five Year Plan and the D022 helps Det 29 determine future fuel requirements based on past activities and consumption, and future-planned activities. Det 29 specifically examines a base´s past two years consumption from D022 reports and significant, projected changes in flying hours, and aircraft assignments reflected in the Five Year Plan. Based on these inputs, personal experience, and some manual computations, Det 29 arrives at the estimated aviation fuel needs for each base (18; 10:23-24).

Estimates for each activity are then sent to the appropriate Major Command´s Energy Management Division for validation (9:14). After validation, the estimates are returned to Det 29 and submitted to DFSC as a MIPR. Any disagreements in estimates are worked out between the Major Command (MAJCOM) and Det 29. Usually the MAJCOM´s revised figures are accepted by Det 29 after additional justification is provided (18). Some of the MAJCOMs solicite requirements inputs from base level as part of validating Det 29´s estimates (15;17;25). These base-level

projections are normally submitted on A.F. Form 761, Bulk Fuels Peacetime Storage (PSO) Objectives Computations, (10:35, 37), or a command unique report such as Air Training Command's 7901 report.

Peacetime Stockage Objective Reports are submitted by base-level Fuels Management Offices to their parent MAJCOM six to nine months prior to the beginning of a new fiscal year. Estimates reflected on the PSO computations are based on the previous one year period prior to the report period, with allowances for deviations based on known missions changes, Air National Guard, or Air Force Reserve training and other "issue experience" (10:37). Figures 2.1 and 2.2 provide an example of Air Force Form 761 and its accompanying instructions (10:35,37).

Internal procedures used by the various MAJCOMs Energy Management Offices are often similar to those used by Det 29. Strategic Air Command's Energy Management Office relies primarily on PSO information from base level for validating their requirements (15).

Tactical Air Command (TAC) also uses PSO information submitted by each base which includes coordinated inputs from each base's Deputy Commander of Operations (DCO) and Accounting and Finance Office, dealing with significant changes in mission and projected and past flying hour data . Headquarters TAC Energy Management Division further verifies these inputs against past

BULK FUELS PEACETIME STOCKAGE OBJECTIVE (PSO) COMPUTATION	REPORT PERIOD FROM	TO	REPORT CONTROL SYMBOL
	1 Apr 80	30 Sep 80	LOG-LO(SA)7308
LOCATION: Homestead AFB FL	SRAN: FP 4829		DATE: 15 Dec 79

COMPUTATIONS	GRADE OF FUEL							
	JP4	145	MGR	MLR	DF2			
	QUANTITIES IN BARRELS							
1. PREVIOUS SIX-MONTHS NET ISSUES 30 Sep 79	428551	18574	6390	247	1595			
2. PERIOD SIX-MONTHS REQUIREMENT 30 Sep 80	440052	22486	6959	266	1451			
3. DAILY DEMAND RATE (Line 2 ÷ by 180)	2445	125	39	1.48	8			
4. PIPELINE TIME QUANTITY (Line 3 x resupply time in days)	3668	188	59	2.22	12			
5. SAFETY LEVEL (Line 3 x 2.25 + 33% of line 4)	6418	328	103	3.89	21			
6. COMPUTED PSO (Lines 3 + 4 + 5)	12531	641	201	7.59	41			
7. PSO NO. OF DAYS AVAILABLE (Line 6 ÷ by line 3)	5.1	5.1	5.1	5.1	5.1			
8. ECONOMIC RESUPPLY QUANTITY (ERQ)	0	202	202	195	195			
9. DEVIATIONS TO LINE 6, IF ANY		202	202	195	195			
10. DEVIATIONS APPROVED								
11. TANK BOTTOMS	3815	507	7	2	3			
12. PIPELINE AND MANIFOLD FILL	3411	792	1	0	0			
13. TOTAL ACCOUNTABLE PSO LEVEL (Line 6 + 11 + 12)	19757	1940	.209	9.59	44			
14. ADJUSTED LINE 13 (Total approved PSO)								

REMARKS (Continue on reverse)

DATE	PRINTED SFMO NAME AND GRADE	SIGNATURE
15 Dec 79	John Doe	John Doe
DATE	PRINTED CIVIL ENGINEER NAME AND GRADE	SIGNATURE
	(Civil Engineer Signature not Required)	

AF FORM 761

Figure 2.1 A.F. Form 761, PSO Computation (10:35)

Atch. B-1—Cont.

PART II—INSTRUCTIONS FOR PREPARATION OF AF FORM 761

Line No.	How Computed
1	Past issues reported on this line will cover the one-year period prior to report period. Only issues from stock fund assets will be entered.
2	Projected requirements reported on this line will cover a 12-month period. Determination of requirements will include issue experience, mission changes, Air National Guard and Air Force Reserve training, and seasonal changes. Deviations will be requested in those cases where a 12-month period does not project the true requirement.
3	Divide line 2 by 360 and enter the result.
4	Multiply line 3 by the number of days of pipeline time required to deliver product from source to using activity including discharge and settling time when applicable and enter the result. However, CONUS locations will use no less than one and one-half days for minimum resupply time. Overseas locations will use a standard 10 days resupply time with exceptions as specified in the OVERSEAS TABLE OF RESUPPLY TIME. Criteria for computing pipeline time is: a. Administrative lead time will not be included in pipeline time. b. Settling time, when included in the pipeline time, should be as prescribed in TO 42B-1-1. Settling time should not be included in the pipeline times when authorized inventories and tankage are adequate to receive and dispense simultaneously. c. Tank trucks used to supply bases will be allowed one day pipeline time for each 10 hours of driving time from the source of supply. Interstate Commerce Commission regulations require 8 hours rest after 10 hours of driving when only one driver is with the tractor. d. Tank cars, barges, and tankers used to supply activities will be allowed the number of days derived from actual experience.
5	Multiply line 3 by a factor of 5 and enter the sum (not applicable to overseas locations).
6	Enter the sum of lines 3, 4, and 5.
7	The first quarter will be annotated N/A (not applicable) since it should reflect the same figures reported on line 5. Subsequent quarters will reflect changes to line 5 or the annotated N/C (no change).
8	Enter the ERQ for the modes of transportation listed on AF Form 759. The ERQ, except in those instances where volume rates apply, shall be the average quantitative capacity or minimum tender acceptable by the transport vessel. Contract data can be used to obtain this information.
9	Enter deviations and individually justify each deviation on the computation sheet. Reference to deviations approved in prior periods should not be used. Deviations can be a minus factor to reduce line 6, if appropriate. Overseas locations, including Alaska, may report a deviation (25 percent of PTQ) in addition to an ERQ, whenever the ERQ equals or exceeds the computed PSO level on line 6.
10	Reserved for Det 29 approval and entry.
11	Enter the quantity of fuel contained below the tank service line.
12	Enter the quantity of fuel carried in the base pipeline and maniford system as reported on AF Form 1235, "Physical Inventory (Fuel Missile Propellants.)"
13	Enter the sum of lines 6, 11 and 12.
14	Reserved for Det 29. Enter the sum of lines (5+10) or (6±10) + 11 + 12.
	Use remarks to substantiate deviations or to support any lines of data being reported as deemed necessary. Use attachments if required. NOTE: Use three-digit product code to indicate grade of fuel being reported (example: JP4, DFM, MGR, etc.)

FMO — Fuels Management Office
CE — Civil Engineer or approved representative (signature not required)
NOTE: This form will be completed/reported by the FMO. Information not available will be obtained from the CE.

Figure 2.2 PSO Computation Instructions (10:37)

consumption contained in M-34 and DEIS-I records. They also estimate and validate fuel consumption by multiplying projected flying hours for a particular aircraft, times the hourly fuel consumption rate listed in A.F. Regulation 177-13 (U.S. Air Force Cost and Planning Factors). (25)

The Military Airlift Command's (MAC) Energy Management Division also uses past consumption to validate and forecast future requirements. However, instead of using only the previous year, MAC estimates requirements for each of its bases by using the average of the past four years consumption taken from M-34 and DEIS-I data. Any mission changes are also taken into consideration, however, MAC's mission requirements have remained relatively stable for the past decade.(20)

Air Training Command relies on past consumption and the 7901 report submitted by its bases to estimate and validate requirements (See Figure 2.3). They have also experimented with a technique of using projected flying hours multiplied times the hourly fuel consumption standard for T-37 and T-38 aircraft listed in A.F. Regulation 173-13 (23). Figure 2.3 depicts an ATC-LGS(A)7901 report submitted by Laughlin AFB, TX.

Procurement and Distribution

As stated earlier, after the requirements have been validated by the MAJCOMs and returned to Det 29, MIPRs consisting of the petroleum requirements for a programmed

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 47TH FLYING TRAINING WING (ATC)
LAUGHLIN AIR FORCE BASE, TX 78843

47 FTW/LGSF 6 January 1984

Avaition Fuel Forecast (ATC-LGS (A) 7901)

HQ ATC/LGSF

1. Subject report is submitted as required:

a. Base: Laughlin AFB, Texas 78843
b. Account: FP3099
c. Product: Jet Fuel, Grade JP-4
d. Procurement Cycle: 1 Oct 84--30 Sept 85
e. Total Requirements:
(1) Total Annual Requirements: 26,281,027
(2) Semiannual requirements:
(a) 1 Oct 84--31 Mar 85: 13,140,514
(b) 1 Apr 85--30 Sep 85: 13,140,513
f. Past annual requirements (SIOATH): 27,068,161
g. Past annual issues: 26,271,301
h. Past annual receipts: 26,219,564
i. Shipment mode: Tank Truck

2. Requirements were formulated on the previous consumption data from 1 Oct 82-- 30 Sept 83, based on past consumption experience, as well as PFT 85-2.

Ira D. Huddleston
IRA D. HUDDLESTON, 1st Lt. USAF
Fuels Management Officer

Figure 2.3 ATC Aviation Fuel Forecasts

delivery period are submitted to DFSC. The MIPRs serve as a basis for bid solicitation between DFSC and the oil companies or storage terminals (13:II-1-6). Contract awards are based on the landed fuel price (16:15). Delivery contracts are often established by the DFR after DFSC negotiates a contract. After the contracts have been awarded, the DFRs or DFSPs are notified and, in turn, issue SIOATHs to the bases in their geographical areas (13:II-4-3). Figure 2.4 illustrates Air Force petroleum requirements, procurement, distribution, and functional relationships.

Forecasting

According to Chambers, Mullick and Smith (5:46-48), determining which forecasting technique to use hinges upon the answers to the following questions:

1. What is the purpose of the forecast - how is it to be used?

2. What are the dynamics and components of the system for which the forecast will be made?

3. How important is the past in estimating the future?

The answer to the first question can determine the accuracy and power needed, and can influence the selection of the technique required (5:46). "Techniques vary in their costs, as well as in scope and accuracy (5:46)." the manager must decide how the range of accuracy or inaccuracy will influence his decisions or operations

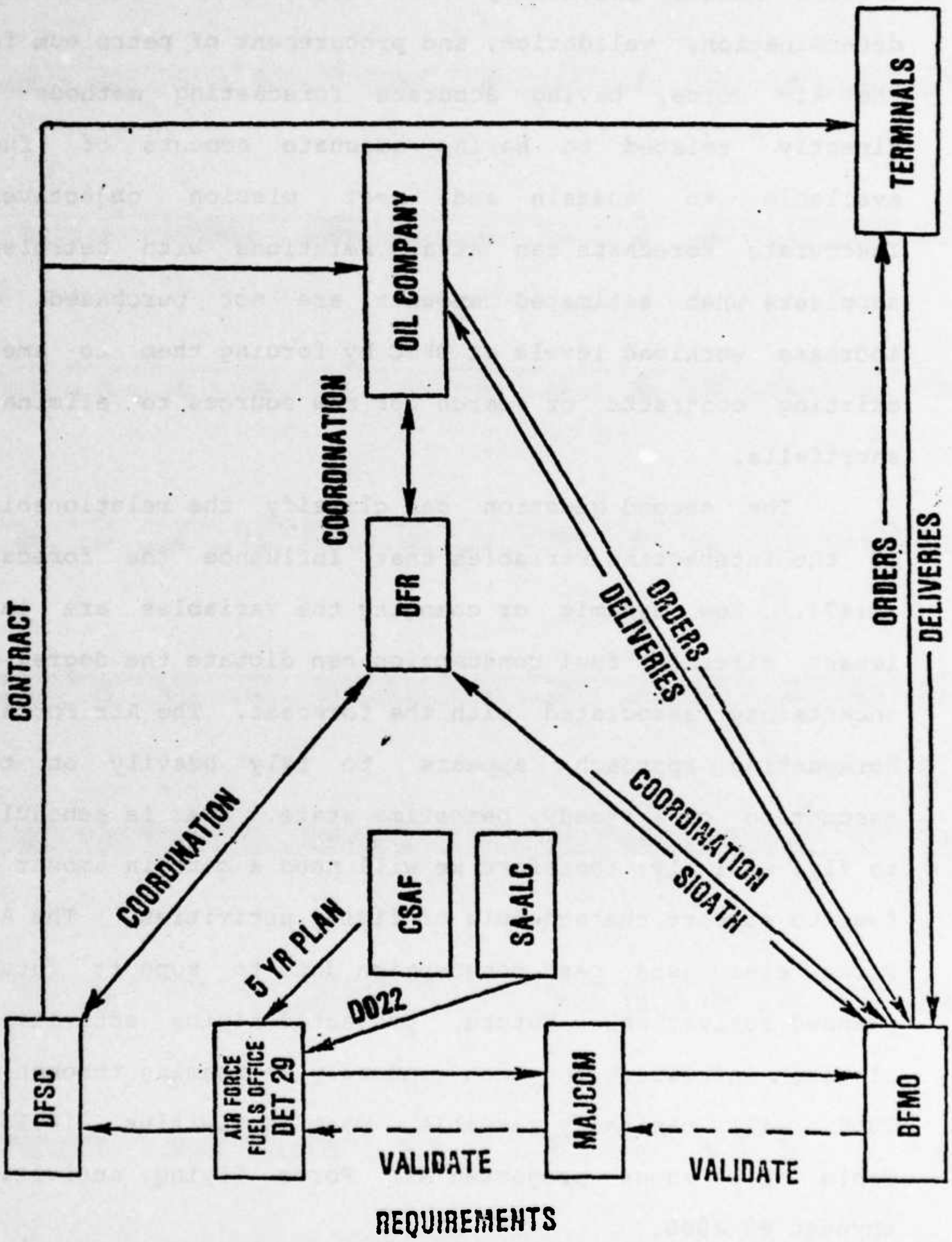

Figure 2.4 DFSC and Fuels Management Office Functional Relationship (9:15)

(5:46). After previously describing the requirements determination, validation, and procurement of petroleum for the Air Force, having accurate forecasting methods is directly related to having adequate amounts of fuel available to sustain and meet mission objectives. Inaccurate forecasts can strain relations with petroleum suppliers when estimated amounts are not purchased, or increase workload levels at DFSC by forcing them to amend existing contracts or search for new sources to eliminate shortfalls.

The second question can classify the relationships of the interacting variables that influence the forecast (5:47). How dynamic or changing the variables are that impact aircraft fuel consumption can dictate the degree of uncertainty associated with the forecast. The Air Force's forecasting approach appears to rely heavily on the assumption of a steady, peacetime state. What is scheduled to fly, will fly; therefore we will need a certain amount of fuel to support the schedule of flying activities. The Air Force also uses past consumption data to support future planned activities. Future, projected flying activities, although increasing and then gradually decreasing through FY 2000, will basically resemble past activities (8:13). Table 2.1 shows projected Air Force flying activities through FY 2000.

The last question posed by Chambers et. al; how important is the past in estimating the future, was essentially addressed in the proceeding paragraph. Will significant changes in flying activities diminish the similarity of the past with the future? Certainly a radical increase in flying activities from one year to the next

TABLE 2.1

Projected Air Force Flying Activities Through FY 2000 [8:13]

Aircraft Type	Programmed FY 1980 Fuel Usage Rate (Gallons per Hour)	Number of Flying Hours					
		FY 1975	FY 1980	FY 1985	FY 1990	FY 1995	FY 2000
A-7	700	95,977	88,905	82,456	76,332	68,953	68,016
A-10	575	453	114,189	234,895	225,154	187,471	186,382
B-52	3,787	152,448	131,985	113,378	103,266	77,906	77,906
FB-111.	1,365	18,902	17,408	17,388	17,508	17,508	17,508
C-5	3,380	50,440	50,463	57,672	57,627	57,627	57,627
C-7	105	14,152	13,310	4,850	4,850	4,850	4,850
C-130	755	331,924	355,954	311,719	307,389	307,389	307,389
C-141	1,970	303,091	283,938	318,518	318,626	318,626	318,626
C-X	3,380[a]	—	—	—	17,792	17,466	16,463
KC-10	2,183[b]	—	—	9,990	21,240	26,820	17,100
KC-135	2,183	225,303	199,425	196,470	199,104	198,757	198,757
F-4	1,612	330,544	289,407	318,577	237,009	208,132	202,918
RF-4	1,350	98,104	74,326	78,965	79,632	24,706	16,260
F-15	1,455	2,983	110,349	165,883	200,390	283,194	280,864
F-16	700	71	14,012	214,598	325,069	325,069	325,069
F-106	925	65,756	63,124	49,850	47,500	—	385
F-111	1,510	83,797	74,402	83,501	79,067	68,551	66,145
FAC-X	1,131[c]	—	—	—	8,480	90,820	90,820
T-33	370	65,067	54,185	53,528	47,788	47,788	47,788
T-37	185	297,123	292,730	344,381	333,543	333,543	333,543
T-38	390	389,984	352,784	403,106	391,296	388,598	388,030
T-39	305	120,154	81,825	4,912	4,912	4,912	4,912
Other[d]	801[e]	990,871	492,274	547,840	544,208	483,618	490,481
Total		3,637,144	3,154,995	3,612,432	3,647,782	3,542,304	3,517,864

[a] Fuel usage rate assumed to be same as for C-5.
[b] Fuel usage rate assumed to be same as for KC-135.
[c] Fuel usage rate assumed to be same as FY 1980 average rate.
[d] Other aircraft types include the A-37, F-100, F-101, F-102, and H-1, which flew significant numbers of hours in FY 1975, but have no flying hours programmed for FY 1985 through FY 2000.
[e] Fuel usage rate assumed to be same as FY 1980 composite average for other aircraft types.

would increase fuel consumption. This, however, does not appear to be the case. Future peacetime flying activities should resemble past activities, and past consumption should therefore serve as a contributing factor in petroleum forecasting.

Forecasting Model

Chambers, Mullick and Smith classify forecasting models into three categories; "qualitative techniques, time series analysis and projections, and causal models (5:49)."

"The first type uses qualitative data, (expert opinion, for example) and information about special events . . . , and may or may not take the past into consideration (5:49)." The basic objective is to integrate in a logical, unbiased, and systematic way all information and judgments related to what is being forecasted (5:49). The authors stated that, often, qualitative methods such as market research and the Delphi technique (expert opinion surveys) are applied to areas that have a great deal of uncertainty associated with them (5:49).

The second and third types of models are often referred to as quantitative techniques and rely on past historical data for producing the forecast (16:17). Time series analyses are statistical techniques that can be used when several years worth of data are available and when both clear and relatively stable relationships and trends are present (5:49-50). Various mathematical techniques can

develop projections after trends and relationships are established or verified (5:50). Chambers, Mullick and Smith cautioned that the difficulty associated with time series techniques are quantifying the rates and trends; they stated: "It is usually difficult to make projections from raw data since the rates and trends are not immediately obvious; . . . (5:50)."

Tersine discussed several of the more common time series techniques and stated:

> There are many techniques for time series analysis. Some of the most common techniques are last period demand, arithmetic average, moving average, regression analysis, and the exponentially weighted moving average. All of the techniques assume some perpetuation of historical forces on future occurrences [26:35].

Regression analysis is sometimes categorized under causal techniques as implied by Chambers et. al. (5:47), and stated by Janke and Pohlen in their research (16:18). Tersine, however, considers regression analysis as a time series technique. We will treat regression analysis as a causal technique and provide a separate discussion on regression analysis (which is our primary research methodology tool) later in this review.

Tersine (26:36-38) addressed the previously listed time series techniques as follows:

> Last Period Demand: This technique simply forecasts for the next period the level of demand that occurred in the previous period. No calculations are required and forecasted values lag behind actual demand by one period.

Arithmetic Averages: Simply takes the average of all past demands in arriving at a forecast. The arithmetic average will smooth out random fluctuations, but will not respond to trends in demand.

Moving Average: Generates the next period's forecast by averaging the last 'n' time periods. The choice of the value of n is arbitrary and should be determined by experimentation. If too few time periods are used, the forecast fluctuates widely, influenced by random fluctuations in demand. If too many periods are included, the average is too stable and current trends are not detected.

The last time series technique described by Tersine, exponentially weighted moving average (EWMA), is a special type of moving average that does not necessarily require lengthy historical records (26:37). This technique assumes that the oldest data period used in the computation has the least value in producing the forecast (26:37). "With the EWMA greater emphasis is given to more recent data and it provides for differential weighting and smoothing (26:37)." Expressed in words, an example (26:37) of the simplest EWMA model is:

June forecast = a (May actual) + (1-a) May forecast

where

a = the exponential smoothing constant between 0 and 1

The last category of forecasting techniques described by Chambers and Mullick are causal models. According to them, causal models are the most sophisticated kind of forecasting tool and by far the best for predicting turning points and preparing long-range forecasts (5:50). They stated:

> When historical data are available and enough analysis has been performed to spell out explicitly the relationships between the factor to be forecast and other factors (such as related businesses, economic forces, socioeconomic factors), the forecaster often constructs a causal model [5:50].

According to Janke and Pohlen, causal techniques are based on the relationship of two or more variables and sufficient historical data to determine the relationship between variables (16:18). Conditions affecting these relationships are assumed to continue on into the future (16:18). "Models falling into this category include regression and correlation analysis, econometric models, input-output models, and systems dynamics (16:18)."

<u>Regression and Correlation Analysis</u>

Tersine (26:36), stated that regression establishes the temporal relationship for the forecast variable and implies a cause-effect relationship. Tersine stated:

> The simplest type of relationship is linear association. Regression analysis by the least squares method will fit a straight line to a plot of data where the independent variable is time. The line fitted by the method of least squares will be such that the sum of squares of the deviations about the line is less than the sum of the deviations about any other line [26:36].

The regression line (26:36) expressed as the basic equation for a straight line can predict demand (X) as a function of time (t) is:

$$X(t) = a + bt$$

where

t = time
a = y axis intercept (when t = 0)
b = slope of line

An indicator of how well a regression line explains or fits the observed data is the correlation coefficient. Mathematically (26:36), the correlation coefficient can be obtained by:

$$r = \frac{(\sum xy)}{\sqrt{(\sum x^2)(\sum y^2)}}$$

The correlation coefficient will range between -1 and +1. "A high absolute value indicates a high degree of association while a small absolute value indicates little association between variables (26:36)."

"When the coefficient is positive, one variable tends to increase as the other increases, [such as flying hours and fuel consumption]. When the coefficient is negative, one variable tends to decrease as the other increases (26:36)."

The coefficient of correlation, r, is derived from the square root of the coefficient of determination R^2. Like the coefficient of correlation the coefficient of determination indicates the relationship between X and Y on a scale of 0 to 1. The strength of relationship appears less than r, since $R^2 < |r|$ at all but the extremes of 0 and 1. As a result, R^2 provides greater differentiation and better operational interpretation. (21:89-90)

According to Tersine (26:36), figure 2-6 provides a general guideline for interpretation of the coefficient of correlation. Corresponding values for R^2 have been added for clarity.

Absolute Value of Correlation Coefficient	Coefficient of Determination, R^2	Interpretation
.90 - 1.00	.810-1.000	Very High Correlation
.70 - .89	.490- .809	High Correlation
.40 - .69	.160- .489	Moderate Correlation
.20 - .39	.040- .159	Low Correlation
0 - .19	0- .039	Slight Correlation

Figure 2.5 Interpretation of r and R^2 Values [26:36]

The statistical significance of any derived sample correlation coefficient can be verified by using standard statistical tests (26:36), such as t or F tests.

Janke and Pohlen's Analysis of POL Forecasting Models for the DOD

Janke and Pohlen (16) investigated improving forecasting accuracy for several Air Force and Navy installations by employing computer-aided forecasting methods. Their primary methodology included inputting past fuel consumption for the bases they studied into decomposition, forecasting models such as the "Box-Jenkins" technique and the interactive "SYBIL-RUNNER" package.

They concluded that using the SYBIL-RUNNER computer statistical package provided more accurate forecasts for the

for bases they studied (16:72). It should be noted, however, that no particular model was found to be the best for all locations or for all time periods at one location. The accuracy of the forecast was dependent upon choosing the right model for the right location and time period.

They recommended that further research be conducted investigating the relationship between flying hours and fuel consumption, to determine whether programmed flying hours can be used to more accurately forecast fuel requirements (16:70).

Cost Planning Factors

Air Force Regulation 173-13, U.S. Air Force Cost and Planning Factors, provides one quantitative method for computing aviation fuel requirements based on flying hours. Through regression analysis of Air Force flying hour and fuel consumption data, HQ-USAF/ACMC derives fuel consumption factors, in gallons and dollars per flying hour for each type (MDS) aircraft. Fuel consumption factors are computed on an Air Force wide basis, using all MDS data and on an appropriation/Major Command basis where aircraft MDS data is differentiated by using command. Air Force flying hour and fuel consumption data used in the regresion analysis is obtained from the SS-A-41 Summary Report of USAF flying hours, the Aerospace Vehicle Inventory Status and Utilization Reporting System, HAF-LEY (M)7502 and HAF-LEY (M)7504, and the AVFUEL Management Accounting System (AMAS)

(RCS:HAF-ACF(AR)8001) reports for the past eight fiscal quarters (12:12-13).

The derived fuel consumption factors are used in a variety of planning and budgeting activities. The appropriation fuel consumption factors are used to develop and execute the fuels budgets for the Air Force O&M, ANG, AFRES, AFSC and Airlift Service Industrial Fund (ASIF). Flying hour cost estimates (budgets) for Air Force O&M are computed by multiplying the programmed flying hours times the composite fuel price times the appropriation MDS fuel factor (12:13). For Program Objective Memorandum exercises the fuels consumption factor used as one of the budget year factors is expressed as dollars per flying hour, computed by multiplying the composite fuel factors derived from the total Air Force fuel consumption and flying hour data for each MDS times the composite standard price times the programmed flying hours (12:3;28). According to Captain Keith Wawrzyniak, of the Directorate of Comptroller Support (AFAFC/CWMF), this method has consistently resulted in estimates within one percent of actual requirements for the entire Air Force as a whole (28).

III. Methodology

Research Theory

As previously mentioned the Directorate of Comptroller Support (AFAFC/CWMF) has achieved a high degree of success (99 percent accuracy) in forecasting annual aircraft aviation fuel costs and requirements for the entire Air Force based on programmed flying hours and aircraft consumption rates. Using this method it may be possible to forecast annual base fuel requirements. There are, however, several unknown factors which may affect the accuracy of a base level fuel requirement forecasting model based on flying hours. First is the degree of accuracy in predicting actual flying hours based on programmed hours. While individual unit or base deviation in the Air Force model may average out, a particular base may experience a consistent or varied tendency to under or over fly programmed hours, thus reducing prediction accuracy.

Moreover, use of the consumption rates specified for a particular aircraft in AFR 173-13 and programmed flying hours will not, in general, accurately reflect actual base consumption. Not all fuel consumed by an aircraft is issued by its home station; instead some fuel is provided by other bases as the aircraft travels around the country or world. The variability and amount of off station flying will decrease the home base's fuel requirement, and may affect the accuracy of the model. Conversely, a base may host and

provide fuel service to transient aircraft. Projected flying hours of home station aircraft cannot account for fuel needed for transient aircraft. This factor is most difficult to plan for as there are no long range (a year in advance) predictions of what aircraft will arrive and take fuel, save for planned exercises. The amount and variability of these transient issues will increase a base´s fuel requirements and may also affect the accuracy of a model.

Finally, jet fuel may also be required for operating aerospace ground equipment (AGE), fire training and jet engine testing. These issues are classified as nonflying (non-fly) issues and also add to a base´s fuel needs. Their relationship to the base flying activity is unknown. It may have some correlation to aircraft hours or sorties flown, in that for so many hours of flight time there is a corresponding number of hours of preflight and postflight activity which employ AGE equipment.

<u>Research Population</u>

The research population of the study was limited to bases within Air Training Command which have flying missions. This command and its bases were chosen because of the extensive data available on programmed and actual flying hours. Tactical Air Command also had extensive programmed and actual flying data which we

received. However, corresponding fuel data was never received, forcing deletion of TAC from this study. Strategic Air Command (SAC) and Military Air Command (MAC) were contacted for possible participation in the study, however were not included. HQ-SAC/DOTF, which is responsible for flying operations plans and programs, was contacted, however, they did not maintain historical data on the programmed and actual flying hours by base and type aircraft needed for the study. HQ-MAC/LGSF, Energy Management Division was contacted for a source for flying hours. They stated that 60 percent of MAC aircraft fuel requirements were provided by off station locations (20). Such low consumption and flying at the home base location would probably not correlate well. MAC was therefore deleted. Other continental U.S. Commands were not considered because of the low number or lack of aircraft assigned. Commands outside the U.S. were not considered because of potential communication and time difference problems.

The number of bases used in the study was further reduced to those having little or no tenant unit assigned aircraft. This action was taken to reduce or eliminate any latent affect caused by the programmed flying activity of Air National Guard, Air Force Reserve and other Air Force tenant units for which programmed and actual flying hours may be unobtainable. Without this data it is not possible

to accurately account for the effect a tenant unit's flying has on a base's present or predicted fuel requirements. The host and tenant units and aircraft assigned to ATC bases were initially determined from the May 1983 issue of Air Force Magazine which contained the 1983 Air Force Almanac, a listing of all bases and assigned units and aircraft. ATC bases having tenant units were verified by HQ-ATC/LGSF, Energy Management Division. Those having tenant units were deleted from the study. Two exceptions to this criteria were Williams AFB which has a tenant unit of TAC F-5 aircraft and Randolph AFB which has a tenant unit of MAC C-39 aircraft. The F-5s at Williams AFB were treated as home station aircraft since programmed and actual flying hours were available from TAC. The C-39 assigned to Randolph AFB were treated as transient aircraft due to the lack of flying hours data. The remaining bases represent the research population for this study and are listed in Figure 3.1.

Base	Location	Abbreviation	Acct. Number	Tenants % consp.
Columbus	Mississippi	COL	3022	N/A
Laughlin	Texas	LAU	3099	N/A
Reese	Texas	REE	3060	N/A
Sheppard	Texas	SHE	3020	N/A
Vance	Oklahoma	VAN	3029	N/A
Williams	Arizona	WIL	3044	*
Randolph	Texas	RAN	3089	

*TAC F-5s Included as part of Home station aircraft

Figure 3.1 Research Population, Air Training Command

Data Collection

Data for this research was obtained from Headquarters ATC and, Base Fuels Management Offices, and Det 29. The programmed and actual flying hour data was furnished by Headquarters ATC/LGSF (ATC Operational and Maintenance Data Recap Report) and Headquarters TAC/DOXSD as compiled from the RCS:HAF LEY(M) 7504 report. This data represents flying hours broken down by unit and specific aircraft type for each base on a yearly basis, Fiscal year 1978 through FY 1983 for TAC and FY 1980 through FY 1984 for ATC (yearly flying data is listed in Appendix A). Additional flying data broken down by month instead of year was provided for ATC bases and TAC Units for the period October 1982 through March 1984. Monthly flying data for years previous to FY 1983 were not available from TAC. Monthly flying data is listed in Appendix B.

Monthly fuel consumption data was compiled from the M-34 (Monthly Fuels Management Data Report) provided directly by ATC bases. Monthly M-34 data was limited to October 1982 through March 1984 due to the current disposition instructions which require only current fiscal year plus the previous year to be maintained on file. Data obtained from the M-34 included Air Force aircraft issues/defuels, transient aircraft issues/defuels, Air Force non-fly issues, and issues/defuels by aircraft mission, design and series. Individual base (JP-4) issue data used

in this study were obtained primarily from the first and last pages of M-34 listings furnished to us. The following numbered list describes our method of extracting issue data:

Step 1. Non-fly issues were taken from their heading in the "customer" section on page one.

Step 2. Air Force fly issues were obtained (after subtracting out defuels), from their heading in the "customer" section.

Step 3. Total Transient issues were found at the bottom of the "customer" section on page one. This figure included Air Force transient along with transient Army, Navy, etc. issues. To obtain Air Force transient issues, the sum of Army, Navy, Marines, and "other" issues were subtracted from the total transient figure.

Step 4. Home station Air Force (fly) issues were obtained by subtracting Air Force transient from the Air Force fly figure.

Step 5. Fuel consumption associated with home station aircraft were obtained by summing the total T-37 and T-38 consumption found on the last page of the M-34 in the MDS Consumption Data section which reflects all Air Force issues to all types of aircraft. This sum, in all cases, exceeded the figure already obtained for home station issues. The difference is attributed to transient T-37 and T-38 activity. Since access to exact consumption breakdown for transient T-37 and T-38 aircraft was not available, a

ratio based on undergraduate pilot cross-country training sorties was derived and multiplied times this difference (27). This ratio worked out to be 1:3.3 gallons. For every 4.3 gallons of transient fuel associated with T-37 and T-38 aircraft, one gallon was attributed to transient T-37 traffic and 3.3 gallons attributed to T-38 traffic.

<u>Step 6</u>. The quantities derived for transient T-37 and T-38, based on the ratio, were then subtracted from the total issues minus defuels for individual T-37 and T-38 aircraft obtained from the MDS Consumption Data section of the M-34. The following example of an actual base in the study may provide greater clarity:

A.F. Fly	1,258,322	gals	(step 2)
Transient A.F. Fly	- 201,577		(step 3)
Home Station Aircraft Consumption	1,056,745		(step 4)
Total T-37	257,029	gals	
Total T-38	+ 843,942		
Total T-37 and T-38	1,100,971		(step 4)
Total T-37 and T-38	1,100,971	gals	
Total Home Station	- 1,056,745		
Transient T-37 and T-38	44,266		(step 4)
Transient T-37 and T-38	44,266	gals	
Combined Ratio	÷4.3		
Transient T-37	10,285		(step 5)
Transient T-37	10,285	gals	
Ratio T-38	x3.3		
Transient T-38	33,941		(step 5)
Total T-37	257,029	gals	
Transient T-37	-10,285		
Home Station T-37	246,744		(step 6)

Total T-38	843,942 gals	
Transient T-38	-33,972	
Home Station T-38 Issues	810,001	(step 6)

Monthly fuel consumption data is listed in Appendix B. Yearly base fuel consumption data was limited to total fuel issues for each fiscal year as contained in the Defense Energy Information System (DEIS-I). There is no breakdown by type issue or aircraft for other than the previous fiscal year. Yearly base fuel consumption data is contained in Appendix A.

Forecasted Fuel requirements for ATC bases were extracted from RCS:ATC-LGS(A)7901 reports furnished by HQ-ATC/LGSF for FY 82 through FY 84.

Statistical Tests, Criteria, and Assumptions

The following information pertains to the criteria, methods, and assumptions used in performing the statistical analysis of the research data:

1. All regression analysis was performed using the "S" statistical package available on the UNIX computer operating system.

2. All statistical tests were performed using a confidence level of 95 percent.

3. The probability distribution of the error term in the regression models is assumed to be normal, variance of the distributor to be constant for all settings of the independent variable, mean of the distribution is zero and errors associated with any two different observations to be independent (2:408).

4. All research data was obtained from official Air Force reports and sources, and is assumed to be accurate.

Accuracy of the Present Forecasting Model

Step 1. The accuracy of the present forecasting method used at each base under study was examined for fiscal years 82, 83 and first half of 84, using the same method as Janke and Pohlen. This entailed first computing the forecasting error associated with each fiscal year, converting these errors to percent errors (PE), and determining the overall accuracy of each base's method by calculating the mean absolute percent error (MAPE). Forecasting errors were computed for each base by subtracting the actual fuel consumed, as reported in M-34 and DEIS reports, from the initial fuel forecast reported on ATC-LGS(A)-7901 for each period. The resulting difference was then divided by the actual consumption during that particular time period. This provided a percent error, positive or negative, which indicated the degree of forecast error for each fiscal year. The mean absolute error was then calculated for each base by taking the average of the absolute values of percent errors over the two and a half fiscal years. This figure provided an overall indication of the accuracy of each base's forecasting technique since it eliminates the canceling of positive and negative errors and gives emphasis to the magnitude rather than the size of the forecasting error (16:32-33).

Correlation Between Programmed and Actual Flying Hours

Step 2. To determine the degree of correlation between programmed and actual flying hours, programmed annual flying hours were regressed against actual annual flying hours by base for each type aircraft, by aircraft type within the command, and by all assigned aircraft within the command. Degree of correlation was noted by the R^2 value (2:421-424). Utility of each model was further examined, using the two-tailed t test, by comparing the t values for the intercept and slope coefficient to the t value for a 95 percent confidence level (2:412-414). In those situations where all aircraft of a particular category had intercepts that were not statistically different from zero, data was again regressed using a zero intercept (21:156-159). (It would appear that this would be a more accurate representation since if no hours were programmed none would be flown). A 95 percent confidence interval for the coefficient was determined for each of the zero intercept regressions and examined to insure a tight fit between programmed (2:414) and actual flying hours (.90-1.00). Composite regressions, by aircraft type and base, and by base were compared to their component´s regressions to see if they were statistically different. This was accomplished using the Residual Standard Error, F test noted in Figure 3.2 (21:160-165), and a confidence level of 95 percent.

Total variations for all bases combined from composite regression:

$$TVC = (\text{Res std error})^2 x (L-1)$$

where

$$L = \text{total observations all bases}$$

Combined variation of each base from component regressions:

$$CV = \sum [(\text{Res std error each base})^2 x (n-1)]$$

where

$$n = \text{number observations/base}$$

$$F\ calc = \frac{\frac{TVC - CV}{(k-1)}}{\frac{CV}{nk-k}}$$

where

$$K = \text{number of bases } n$$
$$(k-1) = \text{degrees freedom numerator}$$
$$(nk-k) = \text{degrees freedom denominator}$$

H_o : Coefficient of each base is statistically the same

H_a : Not all base coefficients are statistically the same.

Accept H_o if: $Fcalc \leq Fcrit$

Figure 3.2 F Test of Coefficients (Zero Intercept)

If the composite regressions were statistically the same as its components, then the composite regression coefficient would be used in predicting the actual flying hours for the group instead of the individual coefficient.

Accuracy of Programmed Flying Hours to Predict Home Station Aircraft Fuel Requirements

Step 3. The accuracy programmed flying hours yields in predicting home station fuel requirements was determined by a method other than regression of annual programmed flying hours versus fuel issued because of problems with the research data. First, while annual programmed and actual flying data was available by type aircraft and base for four complete fiscal years, corresponding fuel data was only available for two years. Regression based on only two points available for each model would provide weak and possibly inaccurate results.

To obtain an accurate regression model, monthly flying and fuel issue figures were considered. This would provide at least 18 data points for each model. However, regression of monthly programmed flying hours against actual consumption would involve autocorrelation effects since programmed flying hours of one month may be flown in following or previous months. Thus, the errors associated with the dependent variable, fuel issued, would not be independent of one another. This would violate one of our initial assumptions and is not desirable. Furthermore, gallons issued would be more dependent and more strongly correlated to actual hours flown which would provide a more accurate fuel issued per flying hour estimate.

To avoid the problems mentioned, monthly flying data

of actual hours flown was regressed against fuel issued for each type aircraft by base and by command. This provided a coefficient representing gallons issued per hour flown. The degree of correlation was noted by the R^2 value (2:421-424). Utility of the model was further examined using the two-tailed t test, by comparing the t values for the intercept and slope coefficients to the t value for a 95 percent confidence level (2:412-414). In those situations where all aircraft of a particular category had intercepts that were not statistically different from zero, data was again regressed using a zero intercept (21:156-159). Composite regressions, by aircraft type and base, were compared to their components´ regressions to see if they were statistically different using the Residual Standard Error, and the F tested noted in Figure 3.2 (21:160-165). If the composite regressions were statistically the same as its components´ then the composite regression coefficient could be used in estimating gallons required per hour flown for each aircraft instead of the individual base coefficients.

Testing the accuracy of programmed flying hours in predicting home station fuel requirements was accomplished by computing the percent error of the model depicted in Figure 3.3 against the actual fuel issued for each type aircraft at each base for FY 83. This provided an indication of the accuracy programmed flying hours yields in predicting actual fuel requirements.

$$X = (p \times h)\, C + i$$

where

X	=	estimated yearly fuel requirement
p	=	estimated percent of programmed hours that would actually be flown (obtained in answering research question 2)
h	=	programmed hours for particular year
C	=	estimated gallons required per hour flown (obtained in previous regression)
i	=	intercept, estimated gallons required per year (obtained from previous regression if natural regression is used)

Figure 3.3 Aircraft Fuel Requirements Model

Accuracy of Average Non-Fly and Transient Issues

Steps 4 and 5. To determine the accuracy associated with predicting transient and non-fly consumption by using monthly averages (research questions 5 and 6), a confidence interval represented by the following formula was used:

$$C.I. = \mu \pm [t \times \text{std dev} \times (1/m + 1/N)]$$

where

μ = monthly average
t = statistical t value, $\alpha = .05$
std dev = standard deviation for μ
m = number of months to be forecasted = 12
N = sample size = 18

The percent accuracy was calculated by dividing the portion of the above formula within the brackets by monthly base average.

Correlation of Programmed Flying Hours and Non-Fly Issues

Step 6. The degree of correlation between programmed flying hours and non-fly issues was determined in the same

manner and for the same reasons as the accuracy programmed flying hours yields in predicting fuel requirements. Using the same monthly data base the total hours flown for all assigned aircraft at each base was regressed against the non-fly issues for the same period. Degree of correlation was noted by the R^2 value (2:421-424). Utility of each model was further examined using the two-tailed t test, to compare the t values of the intercept and slope coefficients to the t value a 95 percent confidence level (2:412-414). Results of these regressions were a low correlation. Thus, no further testing was done.

Construction and Testing of Base Fuel Requirement Models

Annual base fuel requirement models were constructed for each base using the findings to research questions two through six. Depicted below is the general model used for each base to forecast annual aviation fuel requirements (2) for each base:

$$A = p[(C_{37}\ h_{37}) + (C_{38}\ h_{38})] + 12(i_{37} + i_{38} + t + n)$$

Variable p is the estimator of actual hours to be flown derived from the ratio of actual versus programmed flying hours determined in step two of the methodology. Variable h represents the annual programmed flying hours for each type aircraft assigned to each base, in most cases just T-37s and T-38s. Variable C is the coefficient gallons required per actual flying hour for each type aircraft assigned to a

base, computed in step 3 of the methodology. Variable i represents the constant associated with each aircraft's fuel requirement which would be consumed regardless of actual flying hours. This variable is a monthly average also computed in step 3 when the regression with intercept is used. Variable t represents the average monthly issues to transient aircraft, and variable n represents the average monthly non-fly issues. Both were determined in steps 4 and 5 of the methodology.

Testing each base's model was accomplished by using the annual programmed flying hours for FY 80 through the first half of FY 84 to estimate each base's annual fuel requirements. These figures were then compared to the actual fuel consumed by computing percent error (PE) for each period per base and mean absolute percent error (MAPE) for each base according to the procedures used to compute the accuracy of the present Air Force forecasting method noted in step 1 of the methodology.

The forecasting method that provided the most accuracy was determined by making several comparisons. First, the percent errors between the forecast models and individual base forecasts were calculated for FY 82 through FY 84. This initial comparison provided the number of cases that one method was more accurate than the other. Next, the MAPE for each method, FY 82 through FY 84, for each base were compared indicating which method proved most accurate

at each base. Finally, the MAPE of all bases for each method were compared to determine which method was more accurate for the entire research population.

IV. Results and Analysis

Overview

This chapter contains the results of Chapter III. To aid in the analysis process, statistical and mathematical tables will accompany the written discussion for each research question. The research questions from Chapter One are restated below:

1. What degree of accuracy does the present forecast system yield for bases studied?

2. Can actual flying hours be accurately estimated from programmed flying hours?

3. What degree of accuracy does programmed flying hours yield in predicting home station aircraft fuel requirements?

4. What degree of accuracy does the average transient aircraft issue rate yield in predicting future transient aircraft requirements?

5. What degree of accuracy does the average non-fly issue rate yield in predicting future non-fly requirements?

6. Is there strong correlation between non-fly issues and programmed flying hours and if so, what degree of accuracy does programmed flying hours yield in predicting non-fly fuel requirements?

7. Combining the various predictors for computing home station aircraft, transient aircraft and non-fly fuel

requirements what is the overall accuracy of this type model in predicting a base's fuel requirements?

Accuracy of Present Forecasting System

To answer question one, plus or minus percent errors for each base, for two and one-half fiscal years (three time periods) were obtained using the methodology described in Chapter Three. Table 4.1 provides a listing of the percent errors and MAPEs. Figure 1.1, 1.2, and 1.3 (pp. 5, 6) gives a graphical representation of the percent errors for the bases studied.

Two of the bases, Randolph and Reese, provided reasonably good forecast estimates and were within a mean absolute six percent of actual versus forecasted consumption. The remaining five bases either fluctuated inconsistently, over or under actual consumption from year to year, or significantly (from a percentage standpoint) overstated requirements. Vance AFB overstated their FY 84 (first half) by 27 percent.

Clearly, improving upon the forecast accuracies for most of the bases studied would be desirable. The combined MAPE for all of the bases studied was 12.8 percent.

Correlation Between Programmed and Actual Flying Hours

There is a high degree of correlation between annual programmed and actual flying hours. FY 80 through mid FY 84

TABLE 4.1

Forecast Accuracy

	Forecasted	Actual	Percent Error
Columbus			
FY 84	11,017,017	12,167,023	-9.5
FY 83	20,860,559	24,705,479	-15.6
FY 82	22,538,832	26,137,314	-13.8
MAPE:			13.0
Laughlin			
FY 84	13,646,656	12,142,063	+12.4
FY 83	27,293,313	26,311,793	+3.7
FY 82	35,600,000	28,354,410	+25.6
MAPE:			13.9
Randolph			
FY 84	8,449,969	8,962,649	+5.7
FY 83	16,000,000	17,068,230	+6.3
FY 82	15,856,000	16,615,998	-4.6
MAPE:			5.5
Reese			
FY 84	10,600,000	11,099,411	-4.5
FY 83	23,300,000	24,285,430	-4.1
FY 82	25,200,000	25,116,966	+0.3
MAPE:			3.0
Sheppard			
FY 84	13,062,652	10,590,384	+23.3
FY 83	29,209,071	23,558,299	+24.0
FY 82	19,994,930	17,962,518	+11.3
MAPE:			19.5
Vance			
FY 84	12,500,000	9,841,068	+27.0
FY 83	26,500,000	22,020,908	+18.1
FY 82	28,000,000	23,109,324	+21.2
MAPE:			22.1
Williams			
FY 84	15,807,850	16,034,545	-1.4
FY 83	36,951,915	33,371,601	+10.7
FY 82	43,009,645	33,932,750	+26.7
MAPE:			12.9

actual flying hours were regressed against programmed flying hours; by base for each type aircraft (T-37, T-38 and F-5); by type aircraft combined at each base; and by all assigned aircraft within the command (Table 4.2). The R^2 values in all models, except T-38s at Laughlin AFB, had values of .96 or higher (Table 4.2 col. 5), indicating that 96 percent of the variation in actual hours were explained by the model. The strength of correlation was further supported by the t-values of the slope coefficients (Table 4.2 col. 2). The t-value for each model was above the t-value for a 95 percent confidence level ($t_{\alpha/2}$ = 2.571 for regression of aircraft by base and $t_{\alpha/2}$ = 1.96 for regression of aircraft by command) indicating the slope was statistically different from zero in each case; annual programmed and actual fly hours are related. The t-value for the intercept of each model (Table 4.2 col. 4) was found to be less than $t_{\alpha/2}$, indicating that the intercept values were not statistically different from zero for a confidence level of 95 percent. Since the intercept in each model was not statistically different from zero the data was regressed again using a zero intercept (Table 4.3)

The zero intercept regressions were then examined to see if they would yield a coefficient which was statistically the same for all bases. Table 4.3 column 1 gives the coefficients representing actual flying hours as a percentage of programmed flying hours for each base, and for

TABLE 4.2

Regression of Programmed vs. Actual Flying Hours
Natural Intercept

Aircraft/Base	Slope coef.	Slope t-value	Intercept coef	Intercept t-value	R^2
T-37					
Columbus	.8564	13.3296	5593.010	1.9386	.9833
Laughlin	.9628	15.0100	952.3308	.3402	.9870
Reese	.9124	8.7054	2567.809	.6600	.9619
Sheppard	.8598	10.4751	2044.665	.8216	.9734
Vance	.9117	13.9869	309.6604	.0915	.9849
Williams	.9201	9.7111	4147.479	1.0870	.9697
Randolph	.8009	6.9871	1120.203	.4182	.9421
All	.9523	30.8998	309.7305	.2524	.9666
T-38					
Columbus	.8277	10.1133	5377.261	1.5466	.9715
Laughlin	.8812	4.9987	2061.333	.2489	.8928
Reese	.8356	12.4080	4891.816	1.3372	.9809
Sheppard	.8733	16.5668	3242.735	2.1928	.9892
Vance	1.0040	9.0754	1530.060	.3179	.9649
Williams	.8773	13.0156	5383.976	1.5636	.9826
Randolph	.7970	13.5755	3384.814	1.9383	.9840
All	.9008	31.7709	2131.716	1.7353	.9683
T-37/T-38	.9235	44.7088	1299.564	1.5121	.9671
F-5	.9772	48.4404	261.5395	1.4018	.9987
T-37/T-38/F-5	.9280	53.4407	1093.400	1.5636	.9751

NOTE:

Regression coefficients are based on five observations of programmed flying hours versus actual hours flown for fiscal years 80 through mid-84.

TABLE 4.3

Regression of Programmed vs. Actual Flying Hours
Zero Intercept

Aircraft/ Base	Coef.	Conf. Range	Std Error	Resid Sta Error	Obs.
T-37					
Columbus	.9771	±.0569	.0205	2058.762	5
Laughlin	.9838	±.0372	.0134	1317.287	5
Reese	.9794	±.0663	.0239	1981.575	5
Sheppard	.9242	±.0658	.0237	1606.241	5
Vance	.9174	±.0369	.0133	1541.868	5
Williams	1.0200	±.0655	.0236	2119.818	5
Randolph	.8474	±.0686	.0247	1288.78	5
All	.9596	±.0196	.0100	2358.587	35
T-38					
Columbus	.9505	±.0644	.0232	2208.045	5
Laughlin	.9237	±.1060	.0382	4018.234	5
Reese	.9226	±.0527	.0190	2303.560	5
Sheppard	.9821	±.0688	.0248	1556.738	5
Vance	.9700	±.0677	.0244	2371.88	5
Williams	.9792	±.0552	.0199	2270.872	5
Randolph	.9080	±.0464	.0167	2939.934	5
All	.9473	±.0190	.0097	2474.285	35
F-5					
Williams	1.004	±.0161	.0058	120.4143	5
By Base					
Columbus	.9645	±.0344	.0152	2104.124	10
Laughlin	.9517	±.0498	.0220	3165.376	10
Reese	.9407	±.0371	.0164	2406.747	10
Sheppard	.9510	±.0425	.0188	1735.33	10
Vance	.9391	±.0342	.0151	2293.232	10
Williams	.9949	±.0355	.0157	2282.982	10
Williams*	.9951	±.0268	.0125	1832.354	15
Randolph	.8849	±.0375	.0166	1406.365	10
All	.9529	±.0135	.0069	2413.42	70
All*	.9531	±.0131	.0067	2333.913	75

*includes F-5s

each aircraft type. The overall coefficients were 96 percent for T-37s and 95 percent for T-38s as well as F-5s. The percents were tested to see if they were statistically the same within each aircraft group. The T-37 base coefficients were not statistically the same while the T-38 base coefficients were found to be statistically equal (Table 4.4).

TABLE 4.4

F Test of Zero Intercept Coefficients
Programmed vs Actual Flying Hours

All Bases	Fcalc	Fcrit	Degrees Freedom num	Den.	Difference
T-37s	6.3427	2.45	6	28	yes
T-38s	.10165	2.45	6	28	no
T-37s & T-38	1.4918	2.25	6	63	no
T-37s, T-38s and F-5s	1.6990	2.24	6	68	no

NOTE:

H_o: Zero intercepts do not significantly differ
H_a: The intercepts significantly differ

The coefficient .9531 was found to be statistically the same as the coefficient of each base when regressing flying hours as a base group instead of by type aircraft per base. Thus when flying hours are taken as a base group, 95.31 percent of the programmed hours will yield the estimated actual hours flown. The 95 percent confidence interval for this predictor is 94.00 to 96.62 percent, well

within our targeted range of 90 to 100 percent. It should be noted that the confidence intervals for the base regression models, with the exception of Randolph AFB and Williams AFB, were within the targeted range, while the aircraft type per base models were often outside of the targeted range. This latter result can be attributed to the low number of data points used.

Accuracy of Programmed Flying Hours in Predicting Assigned Aircraft Fuel Requirements

In order to determine the degree of accuracy programmed flying hours would yield in predicting home station aircraft fuel requirements, the degree of correlation between actual flying hours and home base fuel issues must first be determined. Regressing October 1983 to March 1984 monthly hours flown against fuel issued by home station to each assigned aircraft type provided a coefficient representing a gallons issued per actual hours flown consumption rate plus a monthly constant, normally representing fuel issued regardless of flying hours. The R^2 values obtained for these models showed a high degree of correlation (R^2 = .490 - .809) in all but four cases (Table 4.5 col. 2). Two of the four exceptions which showed moderate correlation (R^2 = .160 - .489), were T-37s at Sheppard AFB and T-38s at Randolph AFB with R^2 values of .4686 and .3379 respectively. The two remaining exceptions were the Randolph T-37s which had a low moderate

TABLE 4.5

Regression of Monthly Hours Flown vs. Fuel Issued
Natural Intercept

Aircraft/Base	Slope Coef	Slope t-value	Intercept Coef	Intercept t-value	R^2
T-37					
Columbus	171.6778	5.2178	-122237.9	-.8945	.6298
Laughlin	121.8198	4.3649	114974.6	1.0051	.5435
Reese	119.3353	4.8192	151610.3	1.8050	.5921
Sheppard	129.4767	3.7564	148764.7	1.3603	.4686
Vance	122.2485	5.5835	1570.5	.0164	.6608
Williams	150.3407	4.1710	70508.1	.5175	.5209
Randolph	73.9684	1.9499*	120224.4	1.67890	.1920
T-38					
Columbus	324.8530	4.5691	86761.9	.3136	.5661
Laughlin	349.0910	4.4869	-1854.5	-.0057	.5570
Reese	280.8952	5.7034	88574.2	.4006	.6703
Sheppard	299.5032	4.1705	166662.4	.6745	.5208
Vance	331.2235	7.7611	53336.1	.3580	.7901
Williams	299.4474	4.1320	214350.5	.6679	.5162
Randolph	321.5486	2.8575	45065.7	.1463	.3379
F-5	78.0115	.4074*	339310.4	2.2467	.0103

*Indicates slope coefficient was not statistically significant

correlation of .1920 and the F-5s at Williams AFB which had a very slight correlation of .0103. A scatterplot of Randolph AFB T-37 data showed several (3) exceedingly low observations that would account for the low R^2 value and low consumption rate or slope, which was about one half the rate of other bases. These observations could not be deleted since they were within the independent variable range. The scatter plot of the Williams AFB F-5 data showed a large dispersion with both high and low observations that

would account for the extremely low R^2 value and small slope. We have no good explanation as to why these situations occurred.

Strength of correlation between flying hours and fuel issued was further supported by the utility of the model determined by examining the t-value of the slope coefficient and intercept table (4.5 cols. 2 and 4 respectively). In all but two models the slope coefficient t-value for each model was above the t-value for a 95 percent confidence level ($t_{\alpha/2}$ = 2.120). The exceptions were Randolph AFB T-37s with a fairly close t-value of 1.9499 and Williams AFB F-5s which had a very low t-value of .4074. In the case of Randolph T-37s neither slope coefficient nor intercept t-values were sufficient to make the 95 percent confidence level. In contrast, Williams F-5 t-value for the intercept (Table 4.5 col. 4) met the confidence level requirement (t-value = 2.2467), indicating that an average monthly issue rate would provide a better predictor of requirements. In all other models the intercept t-values were less than t indicating no statistical difference from zero.

Finding the intercept for all base T-37 and T-38 models statistically equal to zero, the data was again regressed using a zero intercept in an attempt to find a general consumption rate for each type aircraft (Table 4.6). The command model consumption rate of 337.5073 gallons per flight hour for T-38s was statistically the same for each

base (Tables 4.6 and 4.7). The T-37 command consumption rate however was found to be statistically different among the bases. It should be noted that the Randolph T-37 rate in the zero intercept model was within the range of the other bases and the F-5 consumption rate a closer approximation to the actual rate of 546 gallons per hour contained in AFR 173-13.

TABLE 4.6

Regression of Monthly Hours Flown vs. Fuel Issued
Zero Intercept

Aircraft/Base	Slope Coef. (gals/fly hr)	Conf. Range	Std Error	Std Resid Error	Obs
T-37					
Columbus	142.4713	± 8.5172	4.0366	71129.3	18
Laughlin	149.6414	±10.0345	4.7557	82698.2	18
Reese	163.0390	±11.6489	5.5208	79452.0	18
Sheppard	175.6401	±13.0518	6.1857	83256.3	18
Vance	122.6024	± 8.1045	3.8410	71134.7	18
Williams	168.8258	± 9.9278	4.7051	75460.5	18
Randolph	137.0936	±11.1940	5.3052	42486.8	18
All	149.7288	± 4.6542	2.3746	96908.1	126
T-38					
Columbus	346.834	±24.4202	11.5736	191086.1	18
Laughlin	348.655	±24.5638	11.6416	207567.5	18
Reese	300.231	±20.1309	9.5407	181726.0	18
Sheppard	347.136	±27.0325	12.8116	187029.5	18
Vance	346.038	±21.4327	10.1577	150450.4	18
Williams	347.316	±22.2970	10.5673	198541.4	18
Randolph	337.890	±27.6710	13.1142	152327.4	18
All	337.507	± 8.6820	4.4296	191742.8	126
F-5	505.667	±48.8400	23.1469		18

NOTE:

One observation is a month's hours flown and fuel issued, computed as described on pages 36-37.

TABLE 4.7

F Tests of Slope Coefficients
Zero Intercept

	Fcalc	Fcrit	Degrees freedom num	Den	Difference
*T-37s	14.7485	2.17	6	119	yes
*T-38s	2.0865	2.17	6	119	no

NOTE:

H_0 : Gallons per flying hour rates do not significantly differ by base.
H_a : Gallons per flying hour rates do significantly differ by base.

The degree of accuracy programmed flying hours yields in predicting aircraft fuel requirements was tested using the computed consumption rates in Table 4.6 and programmed flying hours for FY 1983. In all cases the percent error between actual and forecasted requirements was less than eleven percent (Tables 4.8 and 4.9). It should be noted, however, that the same data points were used to compute the consumption rates and may therefore tend to make the results more accurate. Average consumption rates computed as the mean of gallons issued divided by the hours flown for each month, for Randolph T-37s (139.3464) and Williams F-5s (515.75) were also tested. Since the percent error for the Randolph T-37 average rate was higher than the regression model, the regression coefficient would be used in the base model. In the case of the F-5s the reverse was true and the average coefficient would be used instead. The percent

TABLE 4.8
Accuracy of Fuel Estimates Based on Programmed Flying Hours
T-37/F-5

Aircraft/Base	Actual consump.	Estimated consump.	Percent Error
T-37			
Columbus	7,076,589	6,794,358	-4.0
Laughlin	7,573,713	7,120,775	-6.0
Reese	6,790,159	6,266,668	-7.7
Sheppard	6,822,124	6,876,061	+8.0
Vance	6,573,645	6,596,432	+0.3
Williams	7,784,269	6,962,805	-10.6
Randolph	3,220,098	3,412,941	+6.0
MAPE			6.1
Randolph*	3,220,098	3,469,025	+7.7
MAPE*			6.3
F-5	4,967,654	4,638,782	-6.6
F-5*	4,967,654	4,731,342	-4.8

*Avg. consumption rate

TABLE 4.9
Accuracy of Fuel Estimates Based on Programmed Flying Hours
T-38

Aircraft/Base	Actual consump.	Base Model consump	Base Model Percent error	Command Model consump	Command Model Percent error
T-38s					
Columbus	16,215,910	15,796,167	-2.6	15,371,393	-5.2
Laughlin	17,765,002	17,517,025	-1.4	16,956,945	-4.5
Reese	16,057,449	16,324,009	+1.7	18,350,777	+12.3
Sheppard	14,865,982	14,601,646	-1.8	14,1966,24	-2.7
Vance	14,637,211	15,412,296	+5.3	15,032,344	-2.3
Williams	18,299,699	17,812,225	-2.7	17,309,783	-5.5
Randolph	10,669,286	11,187,315	+4.9	11,187,325	-4.6
MAPE			2.9		5.3

error for command and base T-38 consumption models were compared, with the base model providing a higher overall accuracy of 2.9 mean absolute percent error as compared to the command model with a 5.3 MAPE. As a result of this almost two to one difference in MAPEs the base T-38 coefficients were used in lieu of the command average, in spite of the indication in Table 4.7 that base consumption rates did not significantly differ. The MAPE for the T-37 consumption models was 6.1 percent and 6.3 percent when the average consumption model was used for the Randolph T-37s.

<u>Degree of Accuracy in Using Transient and Non-fly Averages for Predicting Future Requirements</u>

Questions four and five are related by virtue of the methodology employed, and will be answered together.

Monthly, mean transient and non-fly figures were obtained for each of the bases. Their averages were then F tested against the combined mean and variance for all of the bases studied to determine whether all of the individual bases´ means were statistically equal to the combined mean.

For both the transient and non-fly averages, the F calculation resulted in a value greater than the F alpha value for a 95 percent confidence level and corresponding degrees of freedom. The calculations revealed that at least two of the individual base means differed from the combined mean for both transient and non-fly consumption, and

TABLE 4.10

Transient and Non-Fly Averages

	Transient Mean	Transient Std Dev	Non-Fly Mean	Non-Fly Std Dev	Combined Mean
COL	108,202.4	44,299.4	21.906.7	4,679.1	130.109.1
LAM	53,085.8	14,792.7	22.919.7	3,997.1	76,005.5
REE	93,653.7	26,514.4	33,570.3	4,999.6	127,224.0
SHE	147,894.1	42,110.0	15,909.7	3,447.6	163,803.8
VAN	45,896.0	16,498.7	23,217.2	4,671.3	69,086.4
WIL	147,158.5	54,002.8	35,792.6	9390.1	182,950.5
RAN	250,632.3	48,940.4	17,937.2	2,403.8	268,569.5
Combined Mean	120,931.8		24,464.8		145,396.6
Fcalc	60.2		37.4		
Fcrit	2.17		2.17		

therefore individual base averages would have to be used in the final forecasting model (see Table 4.10).

Confidence intervals and the percent accuracy for each of the base means (transient and non-fly) were also calculated. These confidence intervals and percents are listed in Table 4.11. An example of interpreting one base (Columbus AFB) could be verbalized as follows: We are confident that 95 percent of the time, the monthly transient consumption will be within plus or minus 24.6 percent of the mean.

The calculated percent accuracies, for the most part, were fairly low inferring that the number of gallons on either side of the mean that will occur, statistically, 95 percent of the time are close to the mean. Also, the total

TABLE 4.11

Transient and Non-Fly Confidence Ranges

	Transient			Non-Fly		
	Confidence Range		% Error	Confidence Range		% Error
COL	81,532.2	134,872.6	±24.6	19,089.7	24,723.7	±12.9
LAU	44,179.9	61,991.7	±16.8	20,513.3	25,326.1	±10.5
REE	77,690.8	109.616.6	±17.0	30,560.3	36,580.3	± 9.0
SHE	122,542.0	173,246.2	±17.1	13,834.1	17,985.3	±13.0
VAN	35,963.0	55,829.0	±21.6	20,404.9	26,029.5	±12.1
WIL	114,646.4	179,670.6	±22,1	30,139.3	41,445.9	±15.8
RAN	221,168.0	280,096.6	±11.8	16,490.1	19,384.3	± 8.0

TABLE 4.12

Regression Total Flying Hours vs. Non-Fly Issues
Natural Intercept

	Slope		Intercept		
Base	Coef	t-value	Coef	t-value	R^2
Columbus	1.6748	1.7762	8572.59	1.1315	.1647
Laughlin	1.9428	3.3945	7005.916	1.4761	.4187
Reese	1.3493	1.9692	23158.37	4.2898	.1951
Sheppard	.9748	1.4356	9566.154	2.1313	.1141
Vance	1.5813	2.7476	11075.42	2.4520	.320
Williams	3.9226	2.0940	3864.334	.2516	.0178

amount of transient and non-fly consumption for any base in our study is only a small percent of its total consumption. This implies that only a small error will be introduced in the forecast by using the average transient and non-fly figures for each base.

Correlation and Accuracy of Programmed Flying in Predicting Non-Fly Fuel Requirements

The correlation between programmed flying hours and non-fly issues as determined through the degree of correlation between actual flying hours and non-fly issues was inconsistent from base to base and rather weak. Regressing October 1983 to March 1984 total actual flying hours by base against corresponding non-fly issues, the R^2 values obtained were inconsistent, ranging from a high of .4187 for Laughlin AFB, indicating moderate correlation, to a low of .0178 for Randolph AFB, indicating slight correlation (Table 4.12). Further inconsistencies were found in the utility of the models. Only Laughlin and Vance AFBs had slope coefficient t-values which met the 95 percent confidence level ($t_{\alpha/2} = 2.120$) while Williams AFB was close with a t-value of 2.0940. This indicated that the coefficients which represent gallons of non-fly fuel needed to support an hour of flying would be a satisfactory predictor. Of the four remaining bases, Reese, Sheppard and Randolph had intercept t-values which met the 95 percent confidence level indicating that a monthly constant or

average would provide a satisfactory predictor. The remaining base, Columbus had neither slope or intercept t-value that would meet a 95 percent confidence level. It should also be noted that Williams AFB had satisfactory t-values for both slope and intercept.

Since the correlation between programmed and actual flying hours is very high, almost one to one, it is assumed that the low correlation of actual flying hours to non-fly issues would also apply to programmed versus non-fly issues. Thus the moderate to low correlation supported by the R^2 values and varying utility of each base model indicates that there is no overall satisfactory model that could be used to predict non-fly fuel requirements based on either actual or programmed flying hours. Results indicate an average or constant consumption rate based on past history to be the best predictor of future requirements. A comparison of forecasted non-fly issues computed using averages obtained in Table 4.10 col. 3 and forecasted issues computed using the coefficients and constants in Table 4.12 to actual non-fly issues shows a higher accuracy for the averaging model (Table 4.13). Using FY 1983 data the MAPE of the averaging method was lower, 4.46 percent that that of the regression method, 5.43 percent, indicating a higher degree of accuracy for the averaging method. While these percent errors seem rather small it should be remembered that the FY 83 data was used as part of the data set to establish each of these

TABLE 4.13

Percent Error of Forecasted Non-Fly Issues

Base	Act. Fuel Consump.	Forecasted Average consump	P.E.	Regression consump	P.E.
Columbus	279,904	262,880	-6.1	259,018	-7.5
Laughlin	286,030	275,036	-3.8	274,235	-4.1
Reese	417,462	402,844	-3.5	403,126	-3.4
Sheppard	199,604	190,916	-4.4	193,959	-2.8
Vance	274,704	278,606	+1.4	288,414	+5.0
Williams	387,570	429,511	+10.8	445,306	+14.9
Randolph	217,851	215,246	-1.2	217,152	-0.3
MAPE			4.46		5.43

models. Accuracy would most likely be less if other data sets were used as estimated in Table 4.10 using the standard deviation of the average.

<u>Model Accuracy</u>

The last research question deals with the accuracy of the individual base models in determining fuel requirements. Figure 4.1 lists the individual base models, combining all of the predictors for each base:

$$COL = .9531[(142.4713 \times h37) + (346.834 \times h38)] + 12 \times 130109.1$$

$$LAU = .9531[(149.4713 \times h37) + (348.655 \times h38)] + 12 \times 76005.5$$

$$REE = .9531[(163.039 \times h37) + (300.231 \times h38] + 12 \times 127224.0$$

$$SHE = .9531[(175.6401 \times h37) + (347.1362 \times h38)] + 12 \times 163803.8$$

$$VAN = .9531[(122.6024 \times h37) + (346.038 \times h38)] + 12 \times 69086.4$$

WIL = .9531[(168.8258 x h37)+(347.316 x h38)
+ (515.75 x h5)] + 12 x 182950.5

RAN = .9531[(137.0936 x h37) + (337.507 x h38)]
+ 12 x 268569.5

where

h37 = programmed T-37 hours for desired fiscal year
h38 = programmed T-38 hours for desired fiscal year
h 5 = programmed F-5 hours for desired fiscal year

NOTE:
second line (quantities) represents mean transient plus non-fly

Figure 4.1 Individual Base Forecast Models

For the seven bases studied; in the three time periods that initial forecast estimates and actual consumption were available, the model provided values closer to the actual consumption than the initial forecast estimates in <u>seventeen</u> out of <u>twenty-one</u> time periods.

Table 4.14 reflects the outcome of the model´s forecasts compared to the initial base´s forecasts and actual consumption for FY 84, FY 83 and FY 82. Combining all seven bases´ initial forecasts for two and one-half fiscal years, yielded an overall MAPE of 12.8 percent. The MAPE for the model during the same time period resulted a 4.0 percent error, clearly an improvement over existing methods.

In two of the three time periods which the model´s estimates did not improve upon the bases´ initial estimates occurred in the test of the first half of FY 84. This could

TABLE 4.14
Forecast And Model Accuracy

Base/ Year	Actual consump	Model Predicted consump	Percent error	Base Forecasted consump	Per-cent error	Best meth
Columbus						
FY 84	12,167,023	11,433,978	- 6.0	11,017,017	-9.5	mod
FY 83	24,705,479	24,151,838	-2.2	20,860,559	-15.6	mod
FY 82	26,137,314	24,933,534	-4.6	22,538,832	-13.8	mod
MAPE/ FY82-84			4.3		13.0	mod
FY 81	22,727,040	22,442,884	-1.3			
FY 80	21,256,916	22,480,250	+5.8			
MAPE/ FY80-84			4.0			mod
Laughlin						
FY 84	12,142,063	11,742,659	-3.3	13,646,656	+12.4	mod
FY 83	26,311,793	25,549,868	-2.9	27,293,313	+3.7	mod
FY 82	28,354,410	26,384,600	-6.9	35,600,000	+25.6	mod
MAPE/ FY82-84			4.4		13.9	mod
FY 81	24,608,178	24,456,254	-0.6			
FY 80	19,900,398	22,424,006	+12.7			
MAPE/ FY80-84			5.3			mod
Reese						
FY 84	11,099,411	11,355,285	+2.3	10,600,000	-4.5	mod
FY 83	24,285,430	24,117,366	-0.7	23,300,000	-4.1	mod
FY 82	25,116,966	24,732,494	-1.5	25,200,000	0.3	bse
MAPE/ FY82-84			1.5		3.0	mod
FY 81	22,974,462	24,939,028	+8.5			
FY 80	26,418,084	25,569,480	-3.2			
MAPE/ FY80-84			3.2			bse
Sheppard						
FY 84	10,590,384	10,745,116	+1.5	10,600,000	23.3	mod
FY 83	23,558,299	23,443,354	-0.5	23,300,000	24.0	mod
FY 82	17,962,518	17,449,086	-2.9	25,200,000	11.3	mod
MAPE/ FY82-84			1.6		19.5	mod
FY 81	15,246,966	12,553,230	-17.7			
FY 80	14,941,122	13,450,756	-10.0			
MAPE/ FY80-84			6.5			mod

Base/ Year	Actual consump	Model Predicted consump	Percent Error	Base Forecasted consump	Per-cent Error	Best meth
Vance						
FY 84	9,841,068	10,594,678	+7.7	12,500,000	27.0	mod
FY 83	22,020,908	22,837,764	+3.7	26,000,000	18.1	mod
FY 82	23,109,324	23,154,272	+0.2	28,000,000	21.2	mod
MAPE/ FY82-84			3.9		22.1	mod
FY 81	23,787,624	23,204,254	-2.2			
FY 80	24,891,392	23,305,174	-6.3			
MAPE/ FY80-84			4.0			mod
Williams[3]						
FY 84	16,034,545	15,261,908	-4.8	15,807,850	-1.4	bse
FY 83	33,371,601	31,701,716	-5.0	36,951,915	10.7	mod
FY 82	33,932,750	32,595,830	-3.9	43,009,645	26.7	mod
MAPE/ FY82-84			4.6		12.9	mod
FY 81	34,595,762	33,326,230	-3.7			
FY 80	36,317,174	33,283,330	-8.2			
MAPE/ FY80-84			5.1			mod
Randolph						
FY 84	8,962,649	10,167,123	+13.4	8,449,696	5.7	bse
FY 83	17,068,230	17,823,090	+4.4	16,000,000	6.3	mod
FY 82	16,615,998	17,377,480	+4.6	15,856,000	-4.6	equ
MAPE/ FY82-84			7.5		5.5	bse
FY 81	14,916,300	15,410,954	+3.3			
FY 80	15,054,396	16,828,242	+4.8			
MAPE/ FY80-84			6.1			bse

NOTES:

1) FY 84 and 83 actual fuel consumption based on M-34 data.

2) FY 80 - FY 82 actual fuel consumption based on DEIS-I data (includes AF Form 15, replacement in kind, Bulk transfers).

3) 5,500,000 gallons are subtracted from Williams AFB figures for Bulk transfers to Arizona ANG FY 80 - FY 82.

be attributed to a reduced smoothing effect of programmed to actual flying hours over short time periods, opposed to a twelve month period in which a base would strive to consume as much of its programmed hours as possible.

The remaining time period which did not show improvement, occurred at Reese AFB which had a low, initial forecast percent errors to begin with.

The model percent errors for FY 80 through FY 82 are particularly important since only flying hours data from these years and not fuel consumption data were used to construct the base models. The MAPE for these three years was only 6.4 percent (actual consumption vs model). The model MAPE for FY 82 was only 3.5 percent compared to the base forecast MAPE of 14.8 percent for the same year. Testing the models for FY 81 and FY 80, in which no initial forecasts were available, the model overall MAPE was 7.0 percent. In all cases the model MAPE for each year proved to be less than the base forecast MAPE of 12.8 percent for FY 82 through mid FY 84 and also less than ten percent.

V. Conclusions and Recommendations

Conclusions

The primary objectives of this study were to examine the merits of the present forecasting system used by the Air Force, specifically, seven bases within the Air Training Command; and investigate the use of a base level forecasting approach based on fuel consumption rates and programmed flying hours to more accurately determine future annual petroleum requirements. The results support this new approach as a more accurate forecasting method for base aviation fuel requirements. There are, however, some cautions about its practical use. While this new approach does produce more accurate forecasts than the present method and normally within ten percent of actual consumption, it does tend to underforecast requirements for most bases. Based on the FY 1980 to mid FY 1984 test results (Table 4.14) at least four out of five period forecasts for four of the seven bases were understated. Even deleting FY 1984 results because of possible autocorrelation with the remaining months the majority of forecasts for five of seven bases were understated. This in reality may not be desirable as additional fuel may need to be procured if the existing on base Peacetime Operating Stock is inadequate to absorb the quantity in error. Such additional fuel needs may still present a problem to DFSC.

As a result further research and "fine tuning" of this approach is needed.

The model forecasts for Williams AFB were consistantly understated while the forecasts for Randolph AFB were consistantly overstated. The cause of this is not quite clear, however one explanation could be the programmed to actual flying hour coefficients. The base coefficients listed in Table 4.3 show the Williams AFB coefficient (.9951) to be higher than the general coefficient (.9531) used in the models while the Randolph coefficient (.8849) is lower. Furthermore the F-5 and T-38 coefficients for Williams, which consume larger amounts of fuel/hour, have even higher individual coefficients of 1.004 and 1.02 respectively while Randolph´s T-37s and T-38s had the lowest individual coefficients of .8474 and .9080 respectively. This is because of the 95 percent confidence level used to insure that base coefficients were statistically the same. This would suggest that allowing a large degree of variation for equality in the coefficients may lead to an over or under bias. Further research is needed to determine if a lower confidence level would eliminate this problem.

The field of this study was limited to seven bases within ATC with little or no tenant flying units. Therefore, the results of this study are not statistically generalizable to other Air Force bases or commands. The methodology employed however may be applied to other bases

and commands and achieve similar statistically accurate results. Prime indicators of such success would be a very high degree of correlation between programmed and actual flying hours, a high degree of correlation between aircraft flying hours and corresponding base fuel issues, and steady transient and non-fly issue rates.

Recommendations

As mentioned the results of this study seem encouraging and through additional research could, perhaps, be applied to other MAJCOMs or services, ultimately enhancing DFSC's procurement mission and the Air Force's readiness posture by having more accurate forecasts and sufficient on-hand operating stocks. The following recommendations are directed at the possible application of this study and future research:

1. Recommend that ATC, Energy Management Division, use the individual base forecasting models obtained from this research to check the requirements inputs from base-level. This would, in effect, facilitate further model testing and provide ATC with a means of adjusting requirements from base-level that differed significantly from quantities derived from the individual models.

2. The methodology of the study's forecasting approach may be applicable to other MAJCOMs with fighter-type aircraft. We recommend further research be conducted

with Tactical Air Command, Alaskian Air Command, and Pacific Command bases using the same or similar methodology.

3. Further research is recommended for bases included in this study. The addition of twelve months of data combined with the eighteen month data base used in this research could strenghthen the model´s accuracy and also facilitate studies into seasonal effects of flying activities.

4. This study´s methodology used a building block approach, finding various consumption rates and factors and adding them together to obtain the final model. We recommend two alternate methodologies be studied and compared to this study using the same and additional data. First alternate methodology involves the use of flying hour and aircraft fuel consumption slope coefficients and regressing it against actual fuel requirements. The resulting intercept would represent a composite of the constant fuel requirements, i.e. intercepts for T-37, T-38, transient and non-fly issues, which were determined individually in the building block approach and their residuals. It is hoped that greater accuracy may be achieved using this method. The second alternate method would employ an averaging technique used to compute the F-5 and Randolph T-37 consumption rates. This method could be used in lieu of the regression technique in the present study. If as accurate or more accurate than the present

study method it may be more useful in the field as a less complex and computer dependent method.

5. The present data maintained by the Air Force is not broken down into categories which facilitate research of this study. It is recommended that obtaining exact or a more accurate breakdown of transient T-37 and T-38 activity within ATC be obtained in future studies, although through sensitivity analysis, the ratio method used in this study did not significantly introduce error in the final outcome.

6. We also recommend that the Air Force improve its management information and data base systems by increasing the document control requirements for the M-34 and other Fuels Management information listings. Future automation efforts may allow for a more extensive and accessible management information system. We also recommend that the proposed revision of the M-34 include a breakdown of home station aircraft consumption by MDS, which would be helpful to base-level fuels managers as well as researchers.

Appendix A: Annual Flying Hours

Columbus AFB

	T-37 prog	T-37 act	T-38 prog	T-38 act
FY84	21622	24358	20984	23185
FY83	50036	49830	47785	45876
FY82	50622	50136	49909	47797
FY81	48240	45228	43353	41663
FY80	47130	44810	43922	38839

Laughlin AFB

	T-37 prog	T-37 act	T-38 prog	T-38 act
FY84	22520	23091	22938	23870
FY83	49984	49607	52714	50871
FY82	49718	50464	55340	53437
FY81	48862	46843	49904	46413
FY80	42061	39978	46704	36273

Reese AFB

	T-37 prog	T-37 act	T-38 prog	T-38 act
FY84	17788	18676	24688	25566
FY83	40328	41027	57047	53634
FY82	39368	39620	59718	54111
FY81	41012	36908	59547	52024
FY80	41412	40761	61533	58497

Sheppard AFB

	T-37 prog	T-37 act	T-38 prog	T-38 act
FY84	18372	17946	17240	18608
FY83	41075	38281	44133	42301
FY82	37979	34272	27582	25615
FY81	20795	21518	21479	22337
FY80	25862	22082	21628	22684

Vance AFB

	T-37 prog	T-37 act	T-38 prog	T-38 act
FY84	26085	24054	20368	19078
FY83	56451	53223	46731	41857
FY82	55863	50090	47899	46055
FY81	57431	50800	47495	47228
FY80	56477	53403	48139	49607

Randolph AFB

	T-37 prog	T-37 act	T-38 prog	T-38 act
FY84	11639	10274	16860	16851
FY83	26120	23402	34778	32064
FY82	24236	21680	34158	30055
FY81	24117	19664	28093	26215
FY80	27268	21385	31219	27384

Williams AFB

	T-37 prog	T-37 act	T-38 prog	T-38 act	F-5 prog	F-5 act
FY84	19580	21861	23690	26212	4219	4400
FY83	43272	45574	53809	52619	9625	9711
FY82	42833	45338	56716	56694	9630	9526
FY81	45568	43466	56163	51868	10593	10595
FY80	44064	44208	56763	56318	10594	10720

NOTE: FY84 Figures Reflect First Half of Year (OCT-MAR)

Appendix B: Monthly Flying Data

Columbus AFB

	T-37s			T-38s				
	hours		gls	hours		gls	gls	gls
	prog fly	act fly	fuel cons	prog fly	act fly	fuel cons	trans cons	non-fly
Mar84	3875	4667	683697	3856	4420	1608090	213377	19656
Feb84	3574	4615	682185	3505	4070	1449233	137264	15844
Jan84	3725	3731	457012	3681	3768	988720	138334	16373
Dec83	2953	3159	510225	2712	2692	1123454	132651	18310
Nov83	3747	4045	561049	3615	3753	1165132	102124	21570
Oct83	3748	4141	566392	3615	4482	1443855	89813	22563
Sep83	4565	4288	691337	4426	3868	1610442	123277	23830
Aug83	4918	4982	731144	4847	4774	1650541	76606	23323
Jul83	4389	4739	707414	4215	3445	1321677	77002	34323
Jun83	4672	4240	512762	4764	3832	1287603	51986	25905
May83	4496	4346	610238	4548	4677	1523080	73973	26882
Apr83	4496	4473	797947	4548	4607	2022966	204670	26769
Mar83	4072	4439	521101	3960	4344	1230377	115649	18856
Feb83	3484	3539	458679	3272	2930	1015333	81316	16855
Jan83	3778	3884	539275	3616	3699	1255321	74482	21039
Dec82	3136	3715	619641	2557	2814	1182781	75819	21717
Nov82	3917	3071	351587	3409	2848	787474	83132	16901
Oct82	4113	4114	534464	3623	4038	1330315	96169	23504

Laughlin AFB

	T-37s			T-38s				
	hours		gls	hours		gls	gls	gls
	prog fly	act fly	fuel cons	prog fly	act fly	fuel cons	trans cons	non-fly
Mar84	3957	4232	668340	4250	4852	1987441	70598	23473
Feb84	3638	4113	605857	3864	4723	1545982	68341	20246
Jan84	3798	3754	429916	4057	3445	980920	48976	17491
Dec83	3114	2575	485256	2937	2897	1269916	68779	21239
Nov83	4006	3929	532211	3915	3567	1143144	41180	21250
Oct83	4007	4488	630309	3915	4386	1365622	23502	22825
Sep83	4608	3566	700089	4892	4163	1805446	46773	27700
Aug83	4997	5486	726269	5357	5003	1580355	41652	25423
Jul83	4413	4935	836181	4659	4770	1935516	25721	32836
Jun83	4759	4552	646454	5291	4692	1445740	50971	24918
May83	4564	4275	598604	5051	4347	1363256	57094	25047
Apr83	4563	4880	861698	5050	4888	2035199	57749	27235
Mar83	4123	4434	591297	4369	4448	1338018	54010	23146
Feb83	3467	3118	482902	3610	3809	1302946	63431	22013
Jan83	3795	3866	538932	3989	3845	1263724	42503	23040
Dec82	2934	3169	559056	2786	3232	1212310	50556	16903
Nov82	3775	3471	480849	3714	3148	1067528	73882	17334
Oct82	3986	3855	551382	3946	4526	1414964	69737	20435

Randolph AFB

	T-37s			T-38s				
	hours		gls	hours		gls	gls	gls
	prog fly	act fly	fuel cons	prog fly	act fly	fuel cons	trans cons	non-fly
Mar84	2047	1592	266018	2963	3393	1442571	324286	19776
Feb84	1883	1835	234543	2715	3277	1014111	269955	16468
Jan84	1965	1693	199596	2839	2594	764919	188793	15909
Dec83	1612	1330	203874	2319	2069	822999	240603	16701
Nov83	2066	1850	266198	3007	2917	965880	256639	20366
Oct83	2066	1974	264673	3008	2610	862862	269112	15799
Sep83	2413	1977	330573	3099	2637	1133870	310040	21483
Aug83	2613	2444	292710	3374	3143	950865	248324	19018
Jul83	2313	2055	348144	2963	2435	1031604	208834	22093
Jun83	2495	2169	215031	3143	2701	621731	154564	15085
May83	2396	1888	236990	3009	2648	842286	301005	18466
Apr83	2396	1818	333666	3008	2875	1116979	342382	21922
Mar83	2076	2049	246416	2969	2762	808921	252654	18110
Feb83	1755	1909	250139	2494	2709	909099	234552	17275
Jan83	1916	1746	231247	2731	2331	708352	187057	16902
Dec82	1584	1580	238865	2170	2381	886160	222664	17753
Nov82	2027	1639	224199	2827	2470	772387	244324	15545
Oct82	2137	2128	272118	2991	2972	887029	255593	14199

Reese AFB

	T-37s			T-38s				
	hours		gls	hours		gls	gls	gls
	prog fly	act fly	fuel cons	prog fly	act fly	fuel cons	trans cons	non-fly
Mar84	3188	3255	621060	4498	4808	1717872	154084	34798
Feb84	2899	3565	591402	4144	4951	1557307	89861	32583
Jan84	3044	3506	472820	4321	4697	1207297	65734	29567
Dec83	2361	2037	469300	3307	2996	1105787	100597	30172
Nov83	3148	3120	418294	4209	3891	1074488	109849	28313
Oct83	3148	3193	490627	4209	4223	1121037	145292	31371
Sep83	3714	3526	697739	5201	4769	1713338	95992	37661
Aug83	4067	4382	677023	5619	5815	1591890	69006	38582
Jul83	3537	4347	771757	4992	5414	1891944	93310	47770
Jun83	3827	4357	642081	5542	5537	1457204	100094	30887
May83	3652	3390	587709	5324	4643	1417778	88782	31886
Apr83	3652	2957	529127	5324	3727	1239817	89551	40054
Mar83	3404	4145	541806	4653	5115	1335968	59782	32215
Feb83	2811	2876	552643	3952	3869	1229206	96142	28720
Jan83	3108	2528	352916	4303	3094	644439	46879	28734
Dec82	2282	1936	380396	3391	2653	886905	75572	33636
Nov82	3042	2829	449387	4264	3806	1137238	101162	30653
Oct82	3232	3754	607575	4482	5192	1511722	104078	36664

Sheppard AFB

	T-37s			T-38s				
	hours prog fly	act fly	gls fuel cons	hours prog fly	act fly	gls fuel cons	gls trans cons	gls non-fly
Mar84	3367	3408	682057	3076	3520	1397129	216035	16117
Feb84	3061	3411	562441	2796	3401	1045110	187093	14409
Jan84	3214	3472	516564	2936	3319	1022938	112558	16112
Dec83	2381	1684	446763	2300	1774	875827	117538	15884
Nov83	3174	3401	541453	3066	3607	1161077	158158	16330
Oct83	3175	2570	386450	3066	2987	874297	200373	7918
Sep83	3653	3142	685153	3872	3772	1615893	210134	22696
Aug83	4000	3881	614300	4241	4273	1321294	140249	16538
Jul83	3478	3495	742199	3687	3885	1695499	114738	23003
Jun83	3971	3425	527313	4390	4193	1274171	76344	15803
May83	3791	3378	565115	4191	3851	1273473	149186	14743
Apr83	3791	3495	731319	4190	3685	1545563	159133	19300
Mar83	3419	3778	595220	3769	3972	1240721	130749	14000
Feb83	2825	2833	454288	3113	2992	870139	119352	12915
Jan83	3122	2206	368191	3441	2517	778950	95518	14766
Dec82	2407	2489	500227	2464	2573	1032222	133110	15143
Nov82	3209	2921	494519	3285	3065	1034684	183209	13013
Oct82	3409	3238	544280	3490	3523	1183373	176086	17684

Vance AFB

	T-37s			T-38s				
	hours prog fly	act fly	gls fuel cons	hours prog fly	act fly	gls fuel cons	gls trans cons	gls non-fly
Mar84	4635	3776	485437	3726	3000	1096341	38722	25460
Feb84	4333	4834	567552	3388	3835	1363263	60522	23909
Jan84	4484	4382	519921	3557	3791	1132609	32397	30174
Dec83	3683	2797	436801	2645	1955	931004	31023	20170
Nov83	4475	4092	488469	3526	3356	1038796	42030	21931
Oct83	4475	4173	403441	3526	3141	943929	85887	21559
Sep83	5113	5065	681585	4373	4188	1605303	39126	30100
Aug83	5456	4783	542430	4789	4509	1475680	47560	27081
Jul83	4943	4685	714796	4164	3691	1537092	27340	31909
Jun83	5269	5574	602120	4682	4812	1615266	36738	26014
May83	5095	5607	703873	4470	4771	1585977	37486	21084
Apr83	5094	4845	688126	4470	3537	1432232	80589	23964
Mar83	4557	4566	609634	3867	3296	1208845	39628	19880
Feb83	3917	3513	314823	3194	2302	546347	26929	14202
Jan83	4266	3230	348587	3531	2233	678198	47607	21677
Dec82	3669	3043	416722	2451	2223	886917	38242	16094
Nov82	4440	3782	444746	3268	2635	888269	64710	21560
Oct82	4632	4530	506203	3472	3660	1177085	39391	21141

Williams AFB

	T-37s hours prog fly	T-37s hours act fly	T-37s gls fuel cons	T-38s hours prog fly	T-38s hours act fly	T-38s gls fuel cons	gls trans cons	gls non-fly
Mar84	3547	3700	704545	4382	4757	1973414	202539	43697
Feb84	3224	3636	574344	3991	4653	1540343	154689	41310
Jan84	3386	3467	508931	4187	4486	1334161	104365	39020
Dec83	2570	3264	599225	3050	3462	1468218	90853	50153
Nov83	3426	3813	635480	4040	4221	1372663	93608	38451
Oct83	3527	3981	600573	4040	4633	1475548	95016	44050
Sep83	4015	4290	843439	4893	4512	1785856	125881	47227
Aug83	4398	5086	761477	5344	5129	1627456	109129	40780
Jul83	3824	4147	829477	4668	4330	1848438	142441	46611
Jun83	4123	4255	660473	5267	5163	1556553	105764	31880
May83	3936	4061	641650	5035	5516	1838168	129392	38066
Apr83	3935	3716	766307	5034	4832	1992751	254622	34248
Mar83	3597	3509	513499	4476	4398	1302575	134232	27754
Feb83	2972	3039	502363	3712	3716	1282445	261906	26050
Jan83	3284	3695	616444	4095	4127	1347948	163488	28751
Dec82	2450	3171	566862	3044	2900	1026787	226743	17216
Nov82	3267	2914	511780	4001	3319	1092780	145648	23113
Oct82	3471	3691	570498	4240	4677	1597942	133056	24928

	F-5s hours prog fly	F-5s hours act fly	F-5s gls fuel cons
Mar84	761	762	465653
Feb84	684	709	336236
Jan84	684	726	365648
Dec83	722	690	392932
Nov83	646	748	341775
Oct83	722	765	338667
Sep83	661	661	480435
Aug83	735	735	396287
Jul83	898	898	472768
Jun83	768	722	413322
May83	725	730	460039
Apr83	897	895	531030
Mar83	810	849	362565
Feb83	887	891	344050
Jan83	896	871	369496
Dec82	800	819	498150
Nov82	929	954	340697
Oct82	710	688	298814

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VITA

First Lieutenant James D. Richardson, Jr. was born on 5 July 1950 in Albuquerque, New Mexico. He graduated from high school in Pittsford, New York in 1968 and attended the State University of New York at Geneseo from which he received the degree of Bachelor of Arts in History/Secondary Education in May 1977. Upon graduation, he enlisted in the USAF and served as a Fuels Specialist in the 21st Supply Squadron at Elmendorf AFB, Alaska. In 1980 he received a commission through the Officer Training School and subsequently served as Fuels Management Officer in the 3380th Supply Squadron, Keesler AFB, Mississippi, until entering the School of Systems and Logistics, Air Force Institute of Technology, in May 1983.

Permanent Address: 5368 Cobb Drive
Dayton, Ohio 45431

VITA

Captain Claude F. Stocky was born on 18 January 1952 in Queens County, New York City, New York. He graduated from Smithtown Central High School, New York, in 1970 and attended the Ohio State University through the four year Air Force ROTC scholarship program. He graduated from Ohio State in 1974 with a Bachelor of Science degree in Industrial Technology Education and received his reserve commission. He was employed as a teacher in the Columbus, Ohio school system until called to active duty in May 1975, and served as assistant Fuels Management Office and Fuels Operation Officer in the 437th Supply Squadron, Charleston AFB, South Carolina. His subsequent assignments as Fuels Management Officer were the 42nd Supply Squadron, Loring AFB, Maine from July 1977 to April 1979; 7020 Air Base Group, RAF Fairford, England from May 1979 to October 1981, and 9th Supply Squadron, Beale AFB, California from December 1981 to May 1983. He entered the School of Logistics, Air Force Institute of Technology in May 1983.

Permanent Address: 4 Ridge Road

Smithtown, New York 11787

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The current Air Force base-level petroleum requirements determination and validation process involves manual computations and analysis at both base and Major Command levels in determining forecast quantities for procurement by the Defense Fuel Supply Center (DFSC). These forecasts often rely heavily on past consumption as the primary basis for future requirements and are often not as accurate as DFSC would like. The purpose of this research is to investigate an alternate forecast method based on programmed flying hours that may more accurately represent and predict future requirements.

Past JP-4 fuel consumption data combined with past programmed and actual flying hours was collected from seven Air Training Command bases. This data was subsequently analyzed using statistical regression analysis which produced consumption coefficients associated with each type of aircraft assigned to each base studied. These prediction coefficients were assembled with mean transient and non-fly consumption and tested using past programmed flying hours multiplied times the prediction coefficients.

The overall results indicated that the regression models' forecast, compared against past forecasts by base and their actual consumption yielded more accurate forecasts in seventeen out of twenty-one time periods.

Several recommendations were also made by the authors that may enhance future studies of this nature.

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